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(71) Applicant: THERAKOS, INC. [US/US]; 437 Creamary Way, Exton, PA 19341 (US).

(72) Inventors: MORRIS, Livingston, B.; 135 Old Lancaster Road, Devon, PA 19333 (US). FRANZ, Dwight; 5 Ridgewood Circle, Haddonfield, NJ 08033 (US). WARKENTIN, Kenneth; 96 Smith Road, Collegeville, PA 19426 (US).

(74) Agents: CIAMPORCERO, Audley, A., Jr. et al.; Johnson & Johnson, One Johnson & Johnson Plaza, New Brunswick, NJ 08933 (US).

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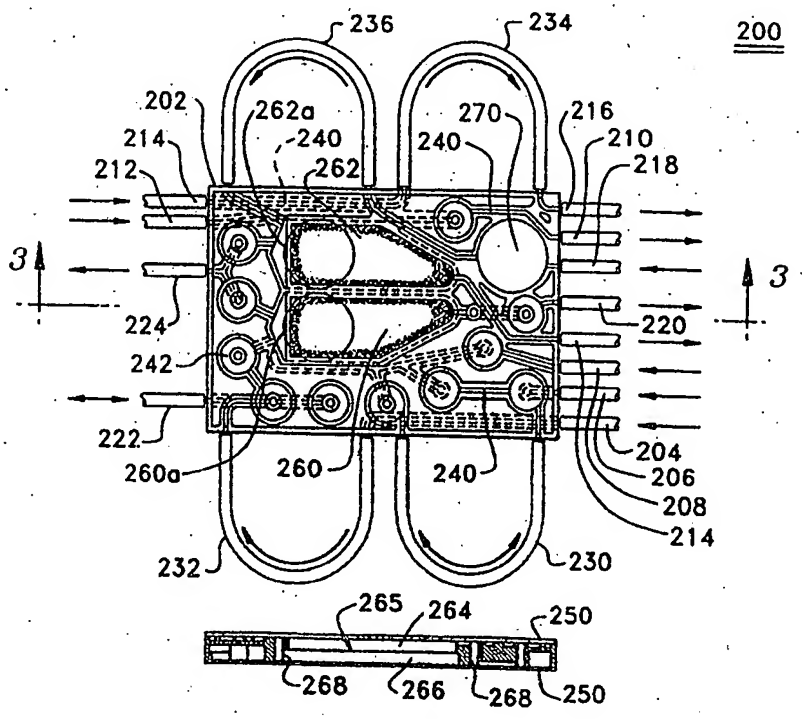
(54) Title: INTERGRATED CASSETTE FOR VALVING, PUMPING AND CONTROLLING MOVEMENT OF FLUIDS

(57) Abstract

An apparatus controls movement of fluids during an extracorporeal blood treatment session. A hollow enclosure has a plurality of fluid input ports for receiving fluids into the enclosure and a plurality of fluid output ports for expelling fluids from the enclosure. A first roller pump tube is provided for pumping at least one of the fluids through the hollow enclosure during the photopheresis treatment session. Internal fluid passageways disposed within the hollow enclosure are provided for coupling together the fluid input ports, the fluid output ports and the roller pump. At least one internal valve is disposed within the hollow enclosure for controlling movement of the fluid within the hollow enclosure.



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INTEGRATED CASSETTE FOR VALVING, PUMPING AND CONTROLLING MOVEMENT OF FLUIDS

FIELD OF THE INVENTION

The present invention relates generally to systems for controlling fluid flow. More particularly, the present invention relates to systems for infusing fluids in and withdrawing fluids from patients undergoing medical care. Still more particularly, the present invention relates to systems for infusing fluids in and withdrawing fluids from medical patients during photopheresis treatment.

BACKGROUND

Several treatments for disease require the removal of blood from a patient, processing the one or more components of the blood and return of the processed components for a therapeutic effect. Those extracorporeal treatments require systems for safely removing blood from the patient, separating it into components, where necessary, and returning the blood to the patient.

Photopheresis is one treatment involving the separation of white cells from the blood, addition of a photoactivatable drug, and U.V. irradiation of the white cells before re-infusion to the patient. In known photopheresis systems, such as system 100 shown in Figure 1, blood fluids are pumped by peristaltic roller pumps 110. In system 100, a complex tubing set is used to couple a patient 120 to an extracorporeal blood treatment system which includes a cell separator 130, a white blood cell photoactivation chamber 140, a saline bag 150a, an anti-coagulant bag 150b and a waste bag 150c. Valves 160, bubble chambers 170, air detectors 180, and pressure sensors 190 are interconnected to the tubing set for monitoring and controlling fluid flow within the system. Complex tubing sets, such as that shown in Figure 1, have the potential to cause cell damage under high outlet pressure conditions. Blood has also been pumped with discrete pump chambers and valves which also require complex tubing sets. Such discrete pump chambers and valves are considered to be less damaging to cells under high outlet pressures.

A very real advancement in photopheresis systems would result if the size and complexity of the tubing in systems such as that shown in Figure 1 could be reduced, even at the cost of a more complex blood driving system, since the blood driving system represents

permanent reusable equipment, whereas the tubing set must be replaced or disposed of after each treatment session. A similar result has been accomplished with peritoneal dialysis systems, where the flow of dialysate is controlled entirely with diaphragm pumps and valves driven by air pulses delivered to a molded cassette through a plastic membrane. See for instance several patents by Dean Kamen, including U.S. Patent No. 5,178,182, issued January 12, 1993 and U.S. Patent No. 5,634,896 issued June 3, 1997, which are incorporated herein by reference.

The cassette contains all components of a previously complex tubing set, except for the lines to the patient and short delivery lines from the dialysate containers. The air pulses delivered to the cassette are controlled by continually analyzing the pressure changes in the air delivered to the diaphragm pumps, processing the pressure changes through a computer, and making continual corrections as a result. The resulting peritoneal dialysis system is able to accurately measure the fluid delivered, but is unable to provide a fixed steadiness of flow rate. In contrast to peritoneal dialysis systems, systems such as photopheresis systems, which involve continuous blood cell separation, require both a very steady flow rate, as well as the ability to control the fluid flow rate. Furthermore, such a system may tend to promote clotting, hemolysis and cell lysis when pumping blood, as opposed to its intended fluid, dialysate which contains no cellular components.

Summary of the Invention

The present invention overcomes these and other limitations of the prior art to provide a system for processing blood without clotting, hemolysis or lysing cells and which achieves an accurate, steady flow rate during extracorporeal treatment of disease. It comprises an apparatus for controlling movement of fluids during a photopheresis treatment session. A hollow enclosure has a plurality of fluid input ports for receiving fluids into the enclosure and a plurality of fluid output ports for expelling fluids from the enclosure. A first roller pump tube is provided for pumping at least one of the fluids through the hollow enclosure during the photopheresis treatment session. The roller pump tube is coupled to the hollow enclosure by a roller pump input port and a roller pump output port. Internal fluid passageways disposed within the hollow enclosure are provided for coupling together the fluid input ports, the fluid output ports and the roller pump input and output ports. At least one internal valve is disposed within the hollow enclosure for controlling movement of the fluid within the hollow enclosure during the photopheresis treatment session.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the manner in which the above-recited and other advantages and objects of the invention are obtained and can be appreciated, a more particular description of the invention briefly described above will be rendered by reference to a specific embodiment thereof which is illustrated in the appended drawings. Understanding that these drawings depict only a typical embodiment of the invention and are not therefore to be considered limiting of its scope, the invention and the presently understood best mode thereof will be described and explained with additional specificity and detail through the use of the accompanying drawings, wherein.

Figure 1 is a block diagram showing a prior art photopheresis system;

Figure 2 is a bottom view of an integrated disposable cassette for valving, pumping and controlling the movement of blood fluids during a photopheresis treatment session, in accordance with a preferred embodiment of the present invention;

Figure 3 is a cross-sectional view of the integrated disposable cassette shown in Figure 2;

Figure 4 is a top view of the integrated disposable cassette shown in Figure 2;

Figures 5 to 27 show in schematic form an alternative embodiment of an extracorporeal blood treatment system according to the invention, including the steps of performing such treatment;

Figure 28 shows in schematic form a further embodiment of an extracorporeal blood treatment system according to the invention;

Figure 29 shows in schematic form a further embodiment of an extracorporeal blood treatment system according to the invention incorporating novel negative pressure and pressure relief valves;

Figure 30 is a cross sectional view through the negative pressure valve of Figure 29;

Figure 31 is a cross sectional view through the one of the pressure relief valves of Figure 29;

Figure 32 is a plan view of a hematocrit detection window in a cassette according to the invention; and

Figure 33 is a cross sectional view taken along lines 33--33 of Figure 32.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to Figure 2, there is shown a bottom (or actuator) side view of an integrated disposable cassette 200 for valving, pumping and controlling the movement of blood fluids during a photopheresis treatment session. Cassette 200 is formed of a hollow injection-molded enclosure 202 having fluid input ports 204, 206, 208, 210, 212 and 214 for receiving fluids into enclosure 202, and fluid output ports 214, 216, 218, 220 and 224 for expelling fluids from cassette 200. Input/output port 222 is provided for both receiving fluid into and expelling fluid from cassette 200. As explained more fully below, these fluid input and output ports couple cassette 200 to a patient being treated, as well as devices in the photopheresis treatment system such as a cell separator 130 and a photoactivation chamber 140 and bags, such as bags 150a, 150b and 150c, containing saline, anticoagulation fluid, and waste fluid, respectively. Significantly, all of the tubing, valves, sensors, drip chambers and pumps shown within box 195 (Figure 1) are implemented within disposable cassette 200.

During a photopheresis treatment session, cassette 200 is snapped into a permanent cassette actuation or driving unit (not shown), and the input and output ports from cassette 200 are coupled to various treatment devices and to a patient. The details of such couplings are explained more fully below. At the conclusion of the treatment session, the cassette 200 is removed from the permanent cassette actuation unit and thereafter is discarded.

Referring still to Figure 2, ports 204, 206, 208 and 214 are provided for coupling disposable cassette 200 to a centrifuge or cell separator. More specifically, output port 214 is provided for delivering whole blood from cassette 200 to the centrifuge, and input

ports 204, 206 and 208 are respectively provided for returning plasma, white blood cells (WBC), and red blood cells (RBC) to cassette 200. Ports 204, 206, 208 and 214 are preferably coupled to the centrifuge with disposable tubing (not shown). Similarly, ports 210, 216, 218 and 220 are provided for coupling disposable cassette 200 to a patient. More specifically, input port 210 is provided for delivering untreated blood from the patient to cassette 200, and output ports 216, 218 and 220 are respectively provided for returning treated blood, saline and an anti-coagulant from cassette 200 to the patient. Ports 210, 216, 218 and 220 are preferably coupled to the patient with disposable tubing (not shown). Input/output port 222 is provided for delivering untreated WBC from cassette 200 to a photoactivation chamber and for returning treated WBC from the photoactivaton chamber to cassette 200. Again, port 222 is preferably coupled to cassette 200 with disposable tubing (not shown). Finally, input ports 212 and 214 are respectively provided for delivering saline and anticoagulant fluid from storage bags (not shown) to cassette 200, and output port 224 is provided for delivery waste fluid expelled from cassette 200 to a waste collection bag (also not shown).

In one preferred embodiment of the present invention, four roller pumps are used to drive the blood fluids described above through the interior of cassette 200. The roller pumps are part of the permanent cassette actuation or driving unit which cassette 200 is snapped into at the inception of each treatment session. More specifically, roller pump tubes 230, 232, 234, and 236 engage the roller pumps in the permanent cassette driving unit when cassette 200 is snapped into the permanent cassette driving unit. Each roller pump tube 230, 232, 234 and 236 is coupled to cassette 200 by two ports which respectively receive and/or deliver blood fluids from and to cassette 200. In the preferred embodiment, roller pump tube 230 is provided for driving WBC through cassette 200; roller pump tube 232 is provided for driving plasma through cassette 200; roller pump tube 234 is provided for driving anti-coagulant fluid through cassette 200; and pump tube 236 is provided for driving untreated blood received from the patient through cassette 200.

Injection-molded enclosure 202 includes internal fluid passageways 240 which are disposed within the interior of cassette 200. As shown in Figures 2 and 4, interior fluid passageways 240 function to couple together fluid ports 204, 206, 208, 210, 212, 216, 218, 220, 222, 224 and roller pump tubes 230, 232, 234 and 236 throughout the interior of cassette 200. Passageways 240 are preferably integral with hollow-enclosure 202, and enclosure 202

and passageways 240 are therefore preferably formed from a singular injection-molded piece of plastic material.

Internal diaphragm valves 242 are disposed throughout the interior of cassette 200. Valves 242 are provided for controlling the movement of the blood fluids that travel through internal passageways 240 during a photopheresis treatment session. Valves 242 are preferably formed as part of the singular injected-molded piece of plastic material used to form enclosure 202 and passageways 240. An elastomeric membrane 250 (shown in Figure 3) covers the upper and lower surfaces of enclosure 202. During a photopheresis treatment session, solenoid valves disposed within the permanent cassette driving unit transmit controlled air or liquid pulses to diaphragm valves 242 through membrane 250 in order to open or close each valve 242. Alternatively, solenoid valves disposed with the permanent cassette driving unit could couple directly to membrane 250 and thereby directly drive valves 242 without any intermediate driving air or liquid.

A pair of drip chambers 260, 262 are disposed within the interior of enclosure 202. As shown more clearly in Figure 3, each drip chamber is formed of compartments 264 and 266 which are separated by a mesh 265. Mesh 265 preferably has a pore size of about 200μ. Each compartment 264, 266 is sealed on one side by membrane 250. In addition, each compartment 264, 266 is connected to an internal fluid passageway 240 within enclosure 202. Again, the walls 268 which form compartments 260, 262 are preferably formed as part of the singular injected-molded piece of plastic material used to form enclosure 202, passageways 240 and valves 242. In the preferred embodiment of the present invention, drip chamber 260 is used for filtering treated blood before it is returned to the patient through output port 220, and drip chamber 262 is used for filtering whole blood before it is delivered to a centrifuge through output port 214. By monitoring the position of the membrane 250 used to form drip chambers 260, 262, the permanent cassette driving device can monitor the pressures of the fluids in drip chambers 260, 262. Thus, in the preferred embodiment, pressure sensors are located on the permanent cassette driving device opposite locations 260a and 262b for monitoring the pressures inside drip chambers 260 and 262. In addition, a pressure sensor is preferably located on the permanent cassette driving device opposite location 270 for monitoring the pressure of untreated blood received from the patient through input port 218.

Figure 5 shows an alternative embodiment of the invention in diagrammatic form. It employs a cassette 300 similar to that shown in Figures 2 to 4, but employing varying valving and porting. A first roller pump 302 pumps an anticoagulant fluid and a second roller pump 304 pumps blood from a patient 306. An anticoagulant bag 308, saline bag 310, centrifugal blood cell separator 312, plasma bag 314, recirculation bag 316 and light treatment chamber 318 connect to the cassette 300 at ports as follows: the anticoagulant bag 308 to an anticoagulant solution port 320, the saline bag 310 to a saline port 322, an inlet 324 on the cell separator 312 to a separator inlet port 326 and an exit 328 from the cell separator 312 to a separator exit port 330, an inlet 332 to the plasma bag 314 to a plasma inlet port 334, an exit 336 from the plasma bag 314 to a plasma exit port 338, an exit 340 from the recirculation bag 316 to a recirculation exit port 342, and an inlet 344 to the treatment chamber 318 to a treatment chamber inlet port 346. Additionally, ports 348 and 350 connect to the anticoagulant roller pump 302, ports 352 and 354 connect to the blood roller pump 304, port 356 connects to an anticoagulant exit line 358 and port 360 connects to the patient 306 via a patient access line 362. A clamp 364 in the patient access line is located upstream of where the anticoagulant line 358 connects to the patient access line 362. A line 368 connects an exit 370 from the treatment chamber 318 to an inlet 372 to the recirculation bag 316.

Internally of the cassette 300, passage 374 connects ports 350 and 356. A pressure sensor 376, comprising an electronic pressure transducer in contact with the membrane (not shown) of the cassette 300, connects to the patient access line port 360. From the sensor 376, passage 378 leads to a first valve 380 and second valve 382. As in Figures 2 to 4, each of the valves of cassette 300 comprise diaphragm valves with the cassette membrane acting to block and unblock a vertical passageway within a valve chamber. From the second valve 382, passage 384 leads to a third valve 386 and fifth valve 388. Passage 384 also leads to an inlet 390 of a filter 392, similar to the drip chamber filter 260 of the prior embodiment. Passage 394 connects the third valve 386 to the saline port 322 and to an eleventh valve 396. Passage 398 connects the fifth valve 388 to port 342. Passage 400 connects the eleventh valve 396 to a sixth valve 402, an eighth valve 404, a seventh valve 406 and to port 352 for the blood pump 304. Passage 408 connects the sixth valve 402 to port 326 and passage 410 connects the eighth valve 404 to port 338 and to a fourth valve 412. Passage 414 connects the fourth valve to port 354 for the blood pump 304 and to port 390 of the filter 392. Passage 416 leads from the filter 392 to the first valve 380. Passage 418 connects the seventh valve 406 to a ninth valve 420 and to a hematocrit detector 422

comprising a light emitting diode and photodector for detecting the presence of red blood cells passing through the detector 422. Passage 424 connects the hematocrit detector 422 to port 346 and passage 426 connects the ninth valve 420 to a tenth valve 428 and to port 330. Passage 430 connects the tenth valve 428 to port 334 and, finally, passage 432 connects port 320 to port 348.

Figures 5 through 27 depicts various stages in a treatment employing the cassette 300, with the dark lines and arrows indicating flows within the cassette 300. Figures 5 to 12 depict the initial priming stages wherein air is displaced from the systems and replaced with fluid. Figure 13 shows blood collection commencing with the clamp 364 removed from the patient line 362. During this step plasma is being separated from the whole blood by the separator 312 and is passed into the plasma collection bag 314. A detector (not shown) for red blood within the separator 362 in connection with a timing delay sets the cassette 300 into the configuration of Figure 14 as the last of the plasma is leaving the separator 362. First, some plasma, and then the buffy coat or white blood cells pass through the hematocrit detector 422 and into the treatment chamber. When the hematocrit detector 422 detects the final blood fraction, the red blood cells, it sets the cassette into the orientation of Figure 15 so as to empty any blood remaining in the separator 312 into the plasma collection bag 314. The plasma is then returned to the patient 306 as shown in Figure 16. The steps shown in Figures 13 to 16 are typically repeated for about six times to amass sufficient white blood cells within the treatment chamber 318.

Figures 17 to 20 depict rinsing steps, and by the final rinsing step the lights (not shown) to the treatment chamber 318 are turned on to begin treating the white blood cells therein. Figure 21 depicts how the white blood cells are recirculated through the treatment chamber 318. Figures 22 and 23 depict the return of the treated cells to the patient 306 and Figures 24 to 26 depict the final rinsing and return to the patient of blood from the cassette 300. Finally, saline from the saline bag 310 is supplied to the patient as shown in Figure 27.

Figure 28 shows how a cassette 434 can be provided employing three roller pumps, including an anticoagulant pump 436, a blood pump 438 and a recirculation pump 440. Having the dedicated recirculation pump 440 allows a cycle to be run whereby white blood cells circulate through the treatment chamber even as plasma is being returned to the

patient. In Figures 5 to 27 the recirculation could not begin until the blood pump 304 was free to be dedicated to that task.

Figure 29 depicts a cassette 500 essentially identical to cassette 300 with the addition of a negative pressure valve 502 into passage 378 and a pair of pressure relief valves 504 and 506 across the ports 352 and 354 of the blood pump 304. The negative pressure valve 502 prevents excessive negative pressure in the passage 378 in communication with the patient line 362. The pressure relief valves 504 and 506 prevent overpressure in the blood pump 304 by recirculating flow through the pump 304 in such an event.

Figure 30 shows a sectional view through the negative pressure valve 502. Its construction is similar to that of the other membrane valves on the cassette 500, having an outlet passage 508 terminating in a valve inlet chamber 510 which is at least partly defined by a flexible membrane 512. Contact between the membrane 512 and a sealing lip 514 at an opening 515 at the termination of the passage 508 into the chamber 510 prevents flow through the valve 502. However, in the negative pressure valve 502, the flow is reversed with flow coming into to chamber 510 and exiting through the passage 508. Thus, if too much flow is drawn by the pump 304 creating a negative pressure at the valve chamber 510, the membrane will be drawn to the lip 514. The membrane 512 is biased so as to close the valve 502 at a predetermined negative pressure. The membrane 512 can be biased in many ways, such as by stretching the membrane 512, by applying a reference fluid pressure to an opposite side 516 thereof, biasing the membrane 51 with a spring, elastomeric member or other known biasing methods as will be apparent to those of skill in the art. Further, while the valve 502 comprises a preferred method of forming a negative pressure valve other known expedients, such as commercially available pressure valves, may be substituted therefor as will be apparent to those of skill in the art.

Figure 31 shows a sectional view through one of the pressure relief valves 504 and 506. The positive pressure relief valves are similarly structured, with an inlet passage 518 terminating in a valve chamber 520 which is partly defined by a membrane 522. Here, flow is in the normal direction, but the membrane 522 normally rests against a lip 524 at the termination of the inlet passage 518 so as to hold the valve normally closed. Again, the membrane is biased, such as by stretching or through application of a reference pressure to an opposite side 526 thereof. When pressure in the inlet passage 518 is sufficient to overcome

the bias on the membrane 522 the membrane lifts away from the lip 524 allowing flow through the valve 504 or 506 and back through the pump 304. While valves 504 and 506 represent a certain preferred embodiment, other biasing means and pressure relief valving may be substituted therefor as will be apparent to those of skill in the art.

Figures 32 and 33 depict a preferred manner of detecting hematocrits. A recessed area 600 is provided in a cassette 602 and membrane 604. The membrane 604 is attached to the cassette 602 at the recessed area 600, rather than being loose. This allows a light emitting diode (LED) 606 or other light source to fit within the recessed area 600 and shine light through a passage 608 at an outside edge 610 of the cassette 602. A photodetector 612 is positioned adjacent the cassette outside edge 610 at this point to monitor the light coming from the LED 606. Red blood cells absorb much more light than plasma or white blood cells so that as the components change in the passage 608 the decreased light reaching the photodector 612 indicates the presence of red blood cells. Preferably, the passage 608 narrows and becomes taller creating an efficient window 614 through which to shine light from the LED 606.

Furthermore, it is to be understood that although the present invention has been described with reference to a preferred embodiment, various modifications, known to those skilled in the art, may be made to the structures and process steps presented herein without departing from the invention as recited in the several claims appended hereto.

WHAT IS CLAIMED IS:

1. An apparatus for controlling movement of fluids during an extracorporeal blood treatment session, comprising:

a hollow enclosure have a plurality of fluid input ports for receiving said fluids into said enclosure and a plurality of fluid output ports for expelling said fluids from said enclosure;

a first roller pump tube for pumping at least one of said fluids through said hollow enclosure during said extracorporeal blood treatment session, said roller pump tube being coupled to said hollow enclosure by a roller pump input port and a roller pump output port;

internal fluid passageways disposed within said hollow enclosure for coupling together said fluid input ports, said fluid output ports and said roller pump input and output ports; and

at least one internal valve disposed within said hollow enclosure for controlling movement of said fluid within said hollow enclosure during said extracorporeal blood treatment session.

2. The apparatus of claim 1, further comprising:

at least one drip chamber disposed within said hollow enclosure, said at least one drip chamber being formed of first and second layers of elastomeric membrane material disposed on upper and lower outer surfaces, respectively, of said hollow enclosure, said at least one drip chamber further including a mesh layer positioned between said first and second layers of elastomeric membrane material, said at least one drip chamber being coupled to said fluid input ports, said fluid output ports and said roller pump input and output ports by said internal fluid passageways.

3. The apparatus of claim 2, further comprising a second drip chamber disposed within said hollow enclosure, said second drip chamber being formed of elastomeric membrane material disposed on said upper and lower outer surfaces, respectively, of said hollow enclosure, said second drip chamber further including a mesh layer positioned between said elastomeric membrane material, said second drip chamber being coupled to said fluid input ports, said fluid output ports and said roller pump input and output ports by said internal fluid passageways.

4. The apparatus of claim 3, wherein said mesh material in said first and second drip chambers has a hole size of about 200 microns.

5. The apparatus of claim 4, further comprising second, third and fourth roller pump tubes, each of said second, third and fourth roller pump tubes being coupled to said hollow enclosure by a roller pump input port and a roller pump output port.

6. The apparatus of claim 5, wherein said first roller pump tube is provided for pumping blood plasma through said hollow enclosure, said second roller pump tube is provided for pumping a white blood cell fluid through said hollow enclosure, said third roller pump tube is provided for pumping blood fluid received from said patient during said treatment session through said hollow enclosure, and said fourth roller pump tube is provided for pumping an anti-coagulant fluid through said hollow enclosure.

7. The apparatus of claim 6, wherein said plurality of fluid input ports include a first input port for receiving said blood fluid received from said patient during said treatment session into said hollow enclosure, a second input port for receiving said white blood cell fluid into said hollow enclosure, a third input port for receiving a red blood cell fluid into said hollow enclosure, a fourth input port for receiving said blood plasma into said hollow enclosure, a fifth input port for receiving said anti-coagulant fluid into said hollow enclosure, and a sixth input port for receiving a saline fluid into said hollow enclosure.

8. The apparatus of claim 7, wherein said plurality of fluid output ports include a first output port for returning blood fluid to said patient during said treatment session, a second output port for expelling whole blood fluid from said hollow enclosure, a third output port for expelling said anti-coagulant fluid from said hollow enclosure, a fourth output port for expelling said saline fluid from said hollow enclosure, and a fifth output port for expelling waste fluid from said hollow enclosure.

9. The apparatus of claim 8, wherein said second, third and fourth input ports and said second output port are coupled to a centrifuge.

10. The apparatus of claim 9, wherein said hollow enclosure is disposable, and wherein said hollow enclosure is adapted to be coupled to a driving means which is

permanent, said permanent driving means including said first, second, third and fourth roller pumps.

11. The apparatus of claim 1 wherein said at least one valve comprises a membrane valve which comprises a first passage terminating in a lip within a chamber, the chamber being at least partially defined by a flexible membrane which has a first position in contact with the lip wherein the passage is occluded by the membrane and fluid communication between the passage and the chamber is blocked by the membrane and a second position out of contact with the lip wherein the passage is not occluded by the membrane and the passage and the chamber are in fluid communication with each other.

12. A method for controlling movement of fluids during an extracorporeal blood treatment comprising the steps of:

extracting blood from a patient and admitting said blood into a hollow enclosure have a plurality of fluid input ports for receiving said blood into said enclosure and a plurality of fluid output ports for expelling said blood from said enclosure and further having ;

pumping said blood with a first roller pump through internal fluid passageways disposed within said hollow enclosure which couple together said fluid input ports, said fluid output ports and said roller pump; and

directing flow of said blood through selected ones of said fluid passageways with at least one internal valve disposed within said hollow enclosure.

13. A method according to claim 12 and further comprising the step of passing at least a portion of said blood through at least one drip chamber disposed within said hollow enclosure, said at least one drip chamber being formed of first and second layers of elastomeric membrane material disposed on upper and lower outer surfaces, respectively, of said hollow enclosure, said at least one drip chamber further including a mesh layer positioned between said first and second layers of elastomeric membrane material.

14. A method according to claim 12 and further comprising the steps of directing said blood through said cassette to an outlet port connected to a blood separator, receiving a separated fraction of said blood back into said cassette and directing said fraction into a first one of said passageways, detecting when said blood fraction comprises red blood

cells and then actuating said at least one internal valve to redirect said blood into a second one of said passageways.

15. A method according to claim 14 wherein when said fraction comprises white blood cells it is directed by one of said at least one valves into a photopherisis treatment chamber.

16. An apparatus for controlling movement of fluids during an extracorporeal blood treatment session, comprising:

a hollow enclosure have a plurality of fluid input ports for receiving said fluids into said enclosure and a plurality of fluid output ports for expelling said fluids from said enclosure;

pumping means for pumping at least one of said fluids through said hollow enclosure during said extracorporeal blood treatment session;

internal fluid passageways disposed within said hollow enclosure for coupling together said fluid input ports, said fluid output ports and said pumping means;

at least one internal valve disposed within said hollow enclosure for controlling movement of said fluid within said hollow enclosure during said extracorporeal blood treatment session; and

a negative pressure valve in fluid communication with one of said fluid input ports, said negative pressure valve having an inlet, an outlet, and a closure member therebetween with a first open position allowing flow between said inlet and outlet and a second closed position for blocking flow between said inlet and outlet, wherein said closure member is positioned to be drawn toward the second position by negative pressures at the valve inlet, the closure member having a biasing means for biasing said closure member into the open position.

17. An apparatus for controlling movement of fluids according to claim 16 wherein said closure member comprises a membrane, an opening between the inlet and outlet, and a sealing lip about the opening, and wherein when the closure member is in the second position the membrane seals against the sealing lip and occludes the opening.

18. An apparatus for controlling movement of fluids according to claim 17 wherein the biasing means comprises a reference pressure applied to a side of the membrane away from the inlet.

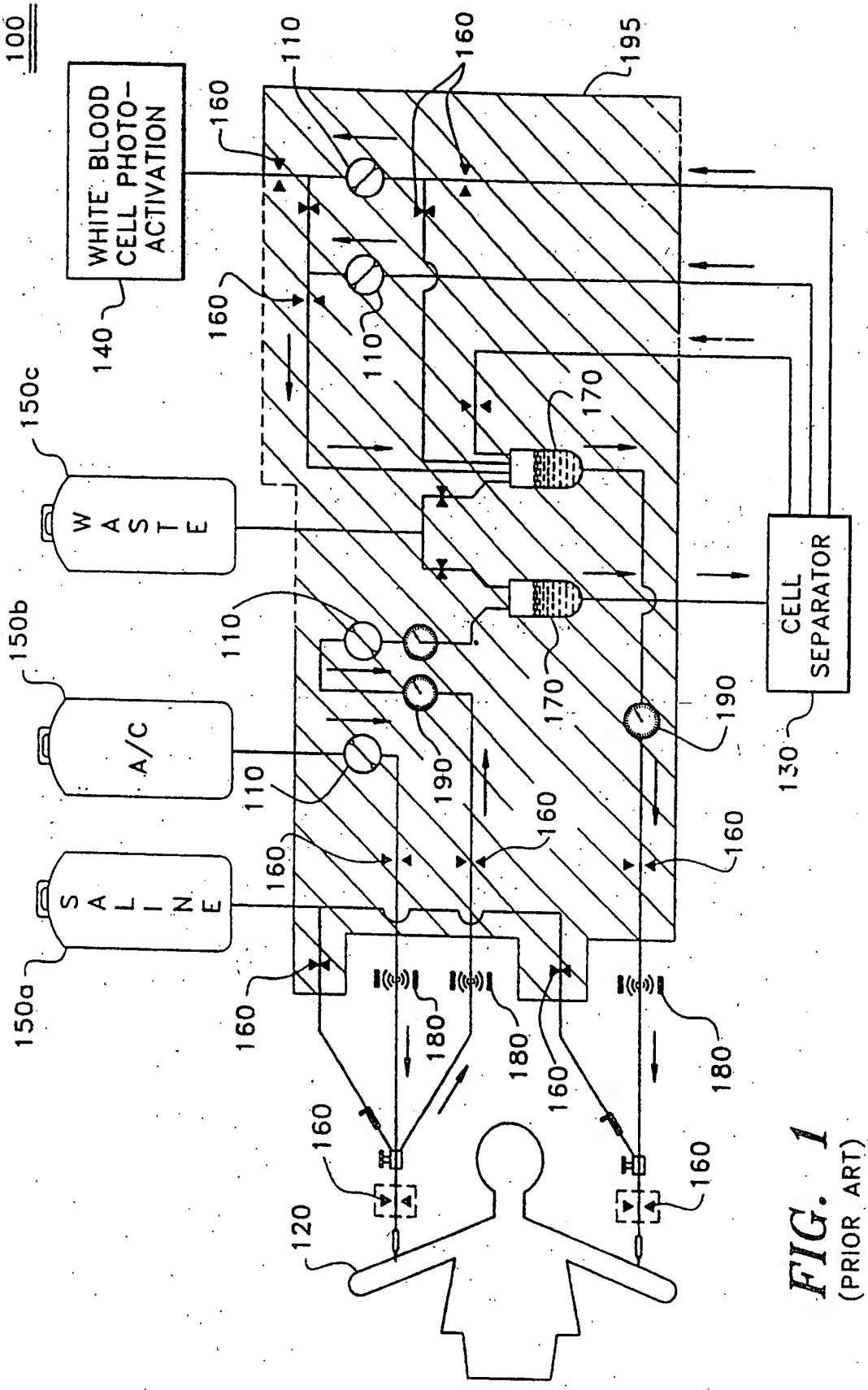


FIG. 1
(PRIOR ART)

FIG. 2

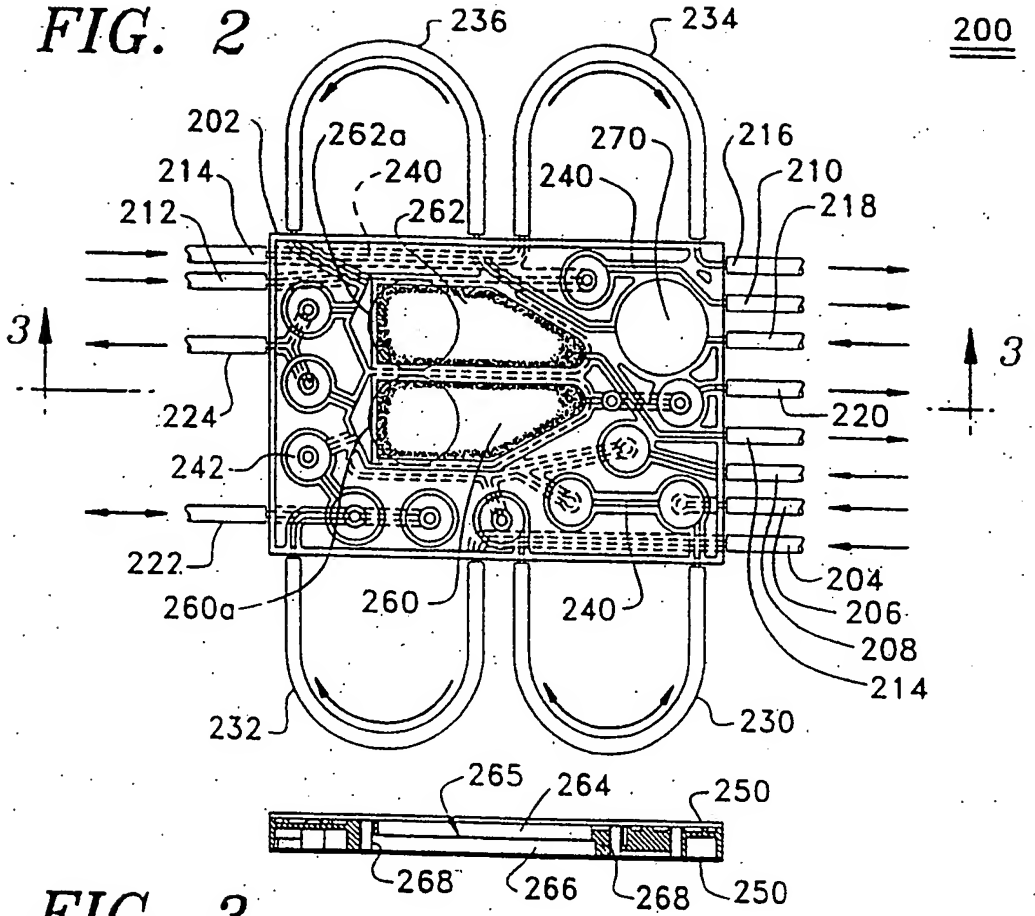


FIG. 3

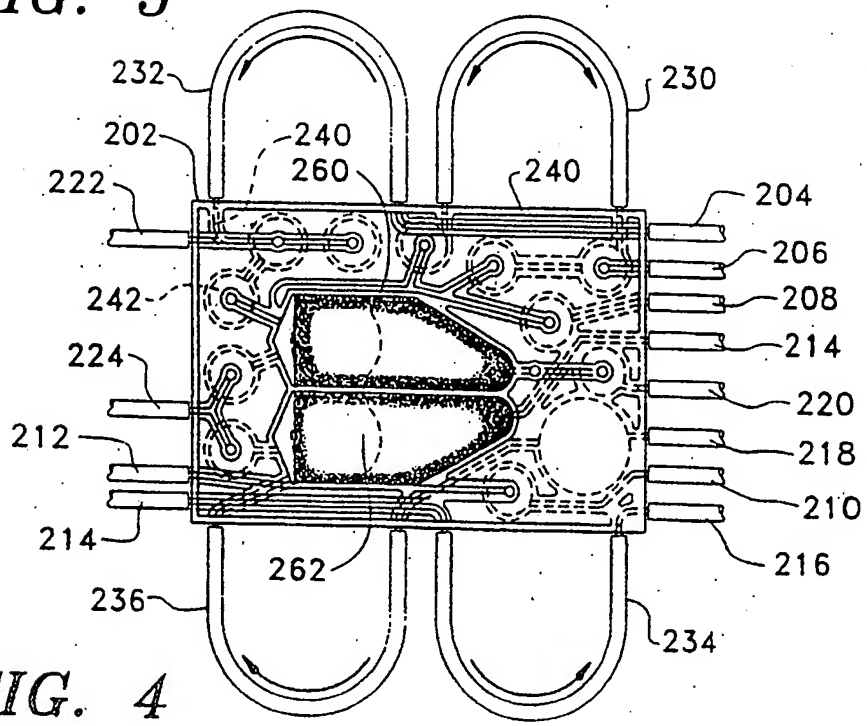


FIG. 4

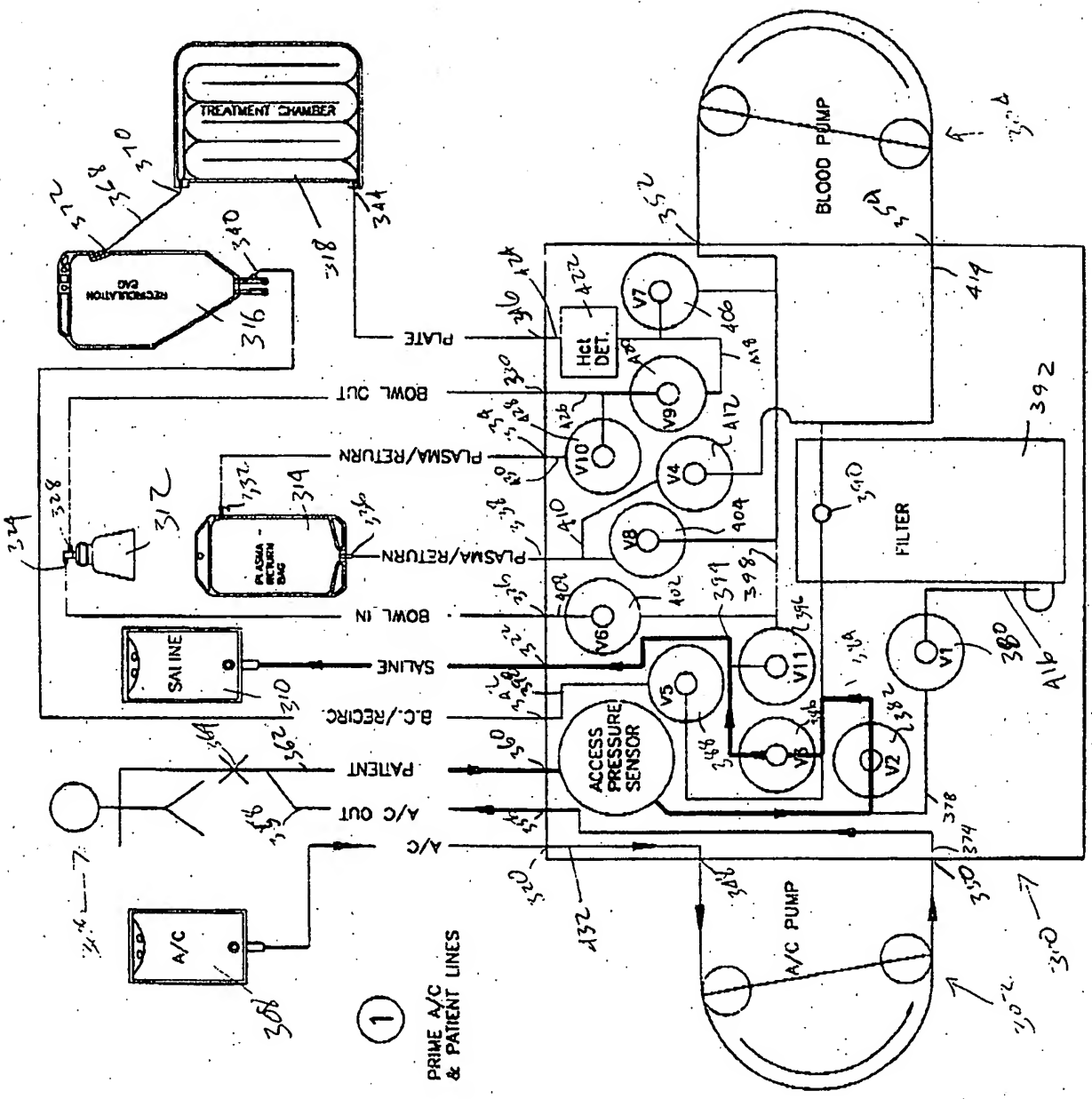

TREATMENT CHAMBER
BLOOD PUMP
FILTER
ACCESS PRESSURE SENSOR
A/C PUMP
Hct DET.
PLATE
BOWL OUT
PLASMA/RETURN
PLASMA/RETURN
BOWL IN
SALINE
B.C./RECIRC.
PATIENT
A/C OUT
A/C
SALINE
A/C
PRIME A/C & PATIENT LINES
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
V11

FIG. 5

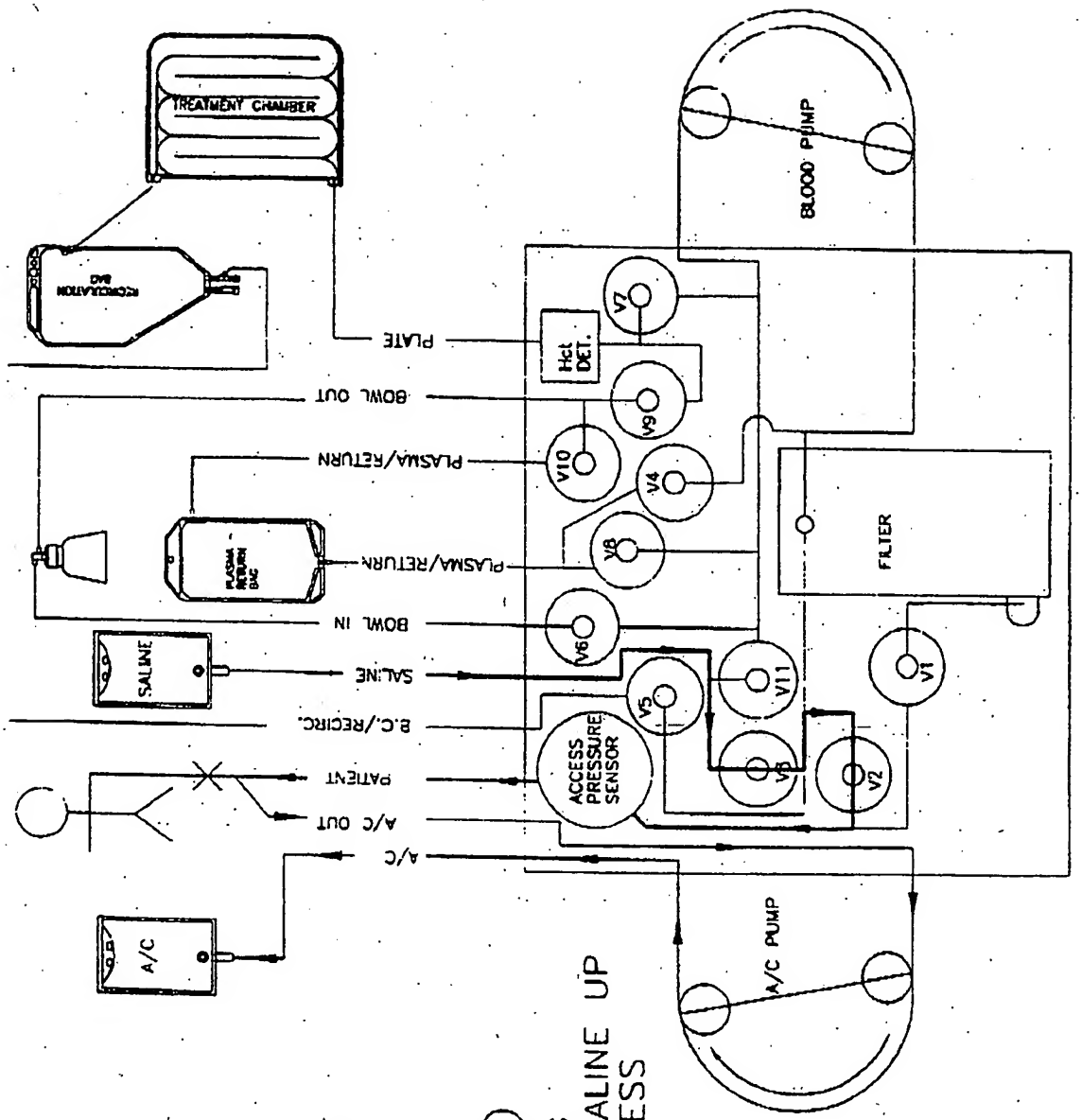


FIG. 6

② PRIMING BACK SALINE UP TO ACCESS

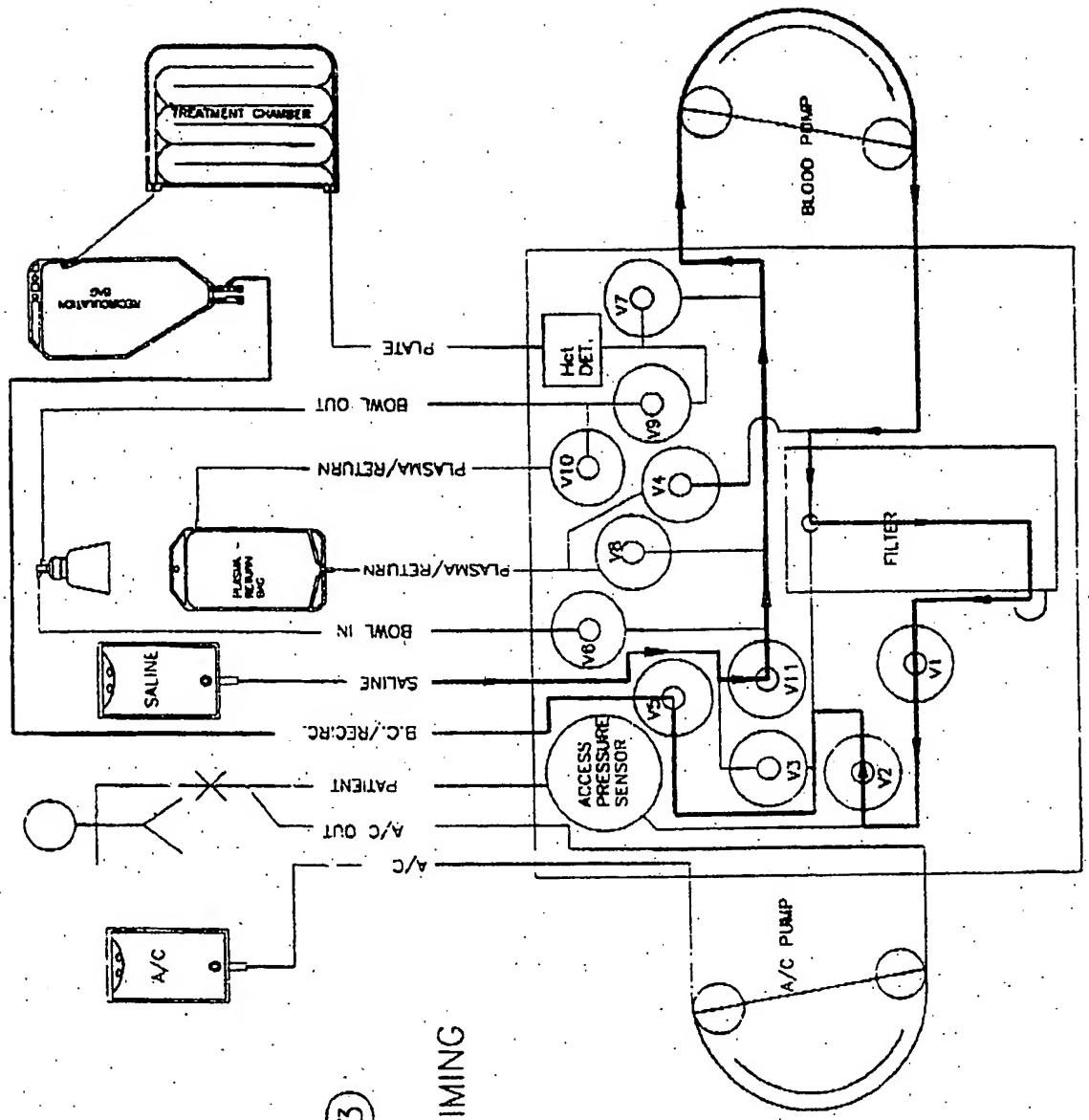


FIG. 7

(3) PRIMING

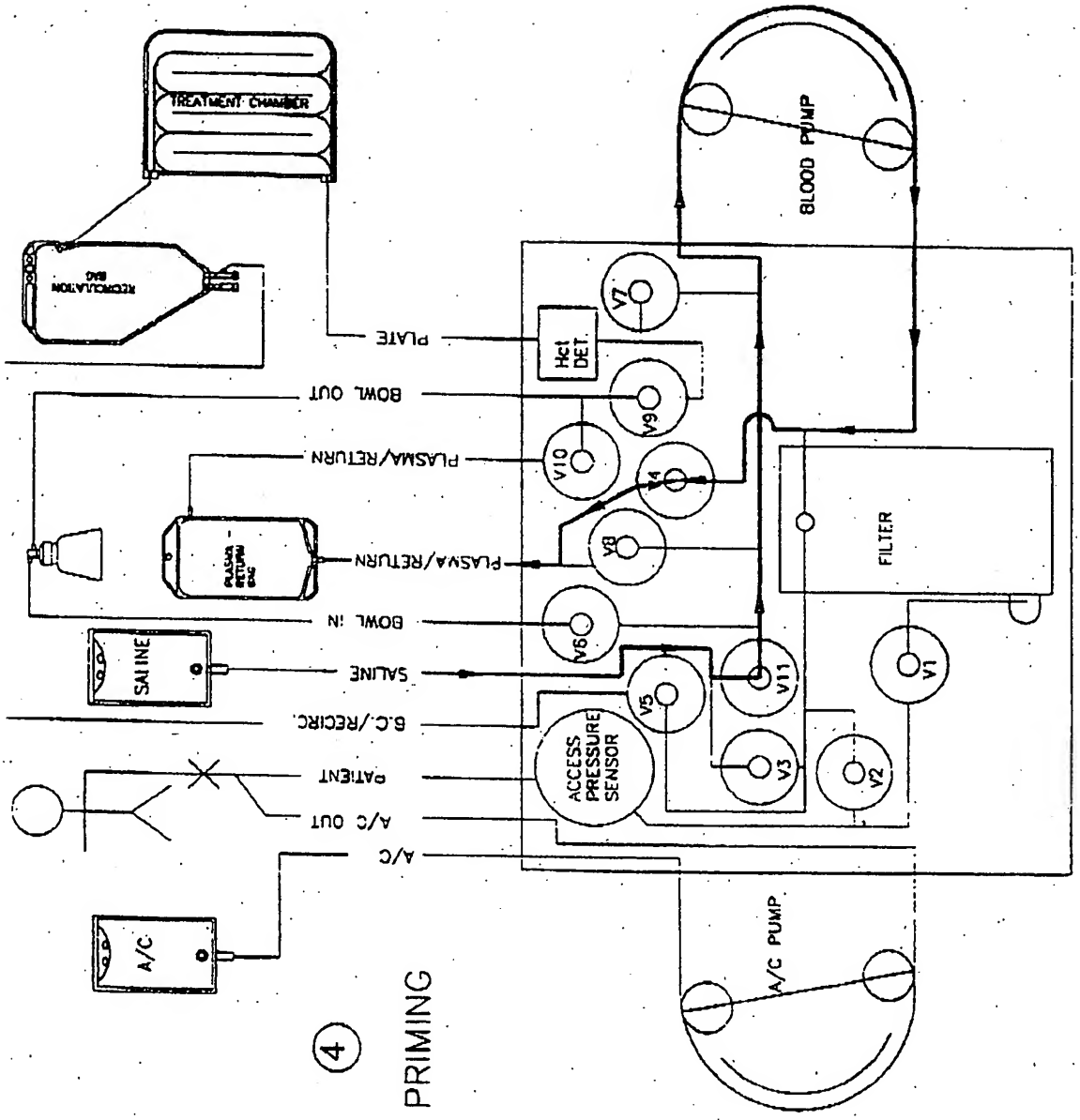

TREATMENT CHAMBER
RECIRCULATION BAG
PLASMA RETURN BAG
SALINE
A/C
PATIENT
BLOOD PUMP
A/C PUMP
FILTER
ACCESS PRESSURE SENSOR
Hct DET
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
V11
PLATE
BOWL OUT
PLASMA/RETURN
PLASMA/RETURN
BOWL IN
SALINE
B.C./RECIRC.
PATIENT
A/C OUT
A/C
4 PRIMING

FIG. 8

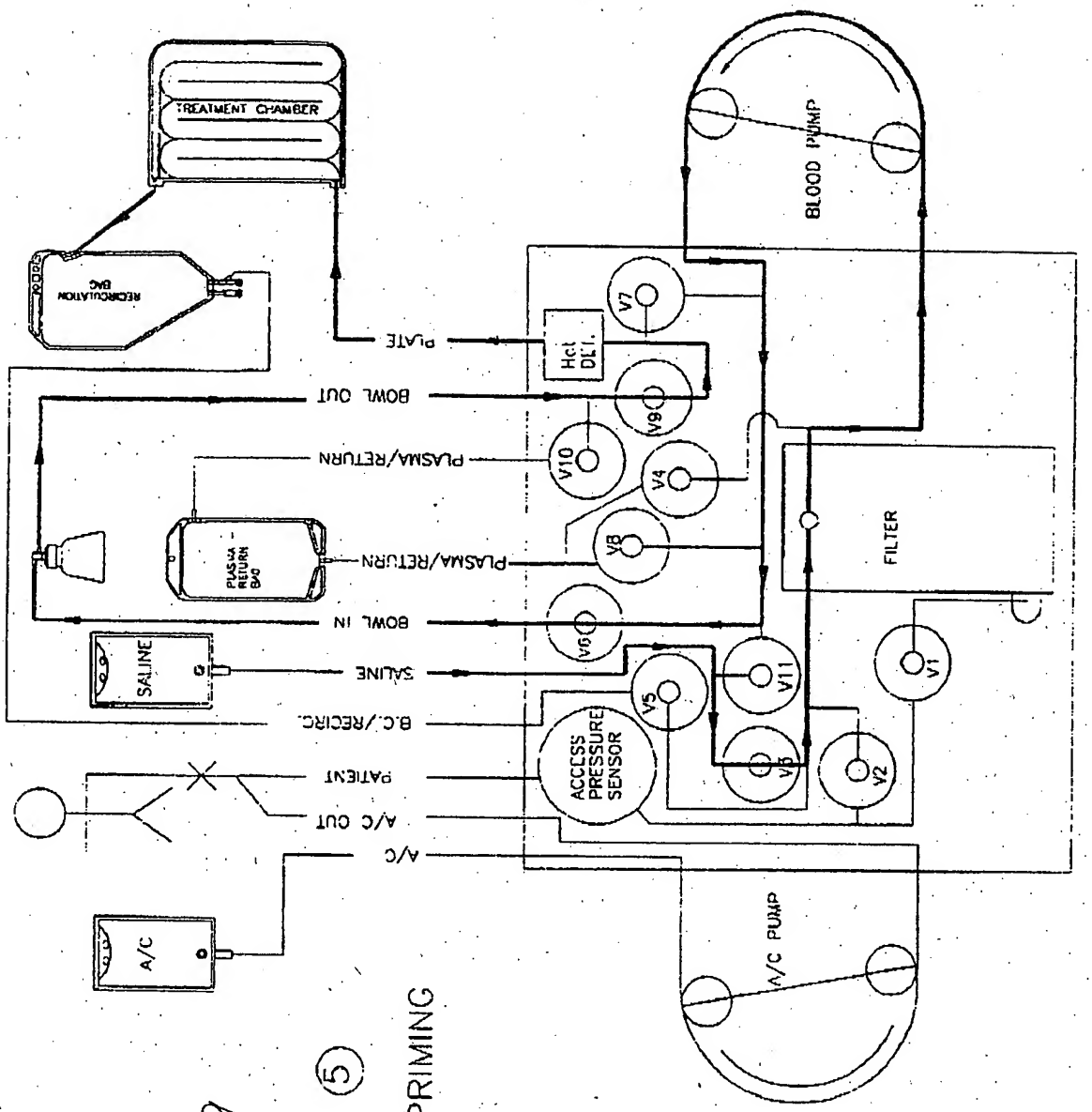


FIG. 9

(5) PRIMING

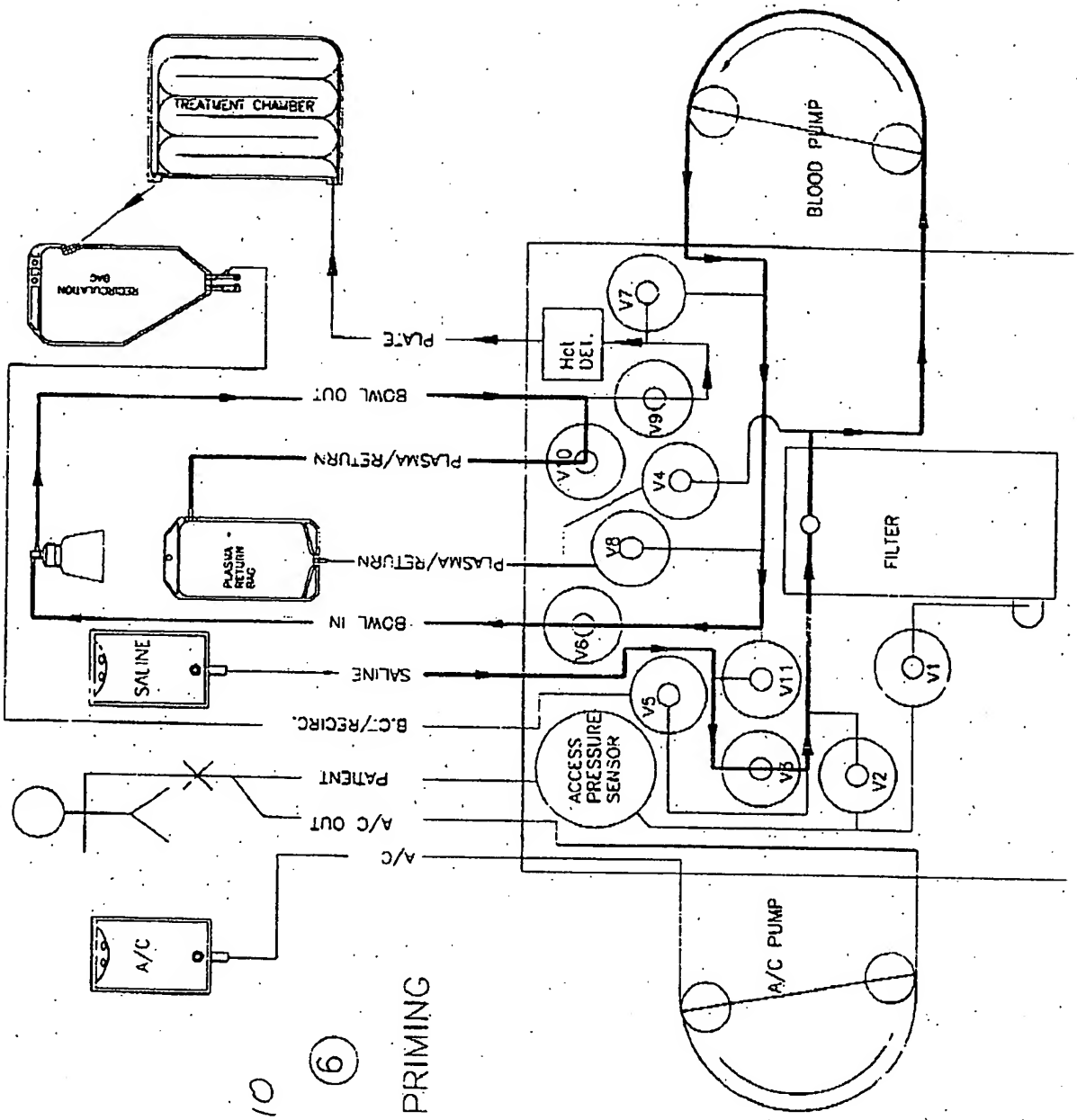


FIG. 10 (6) PRIMING

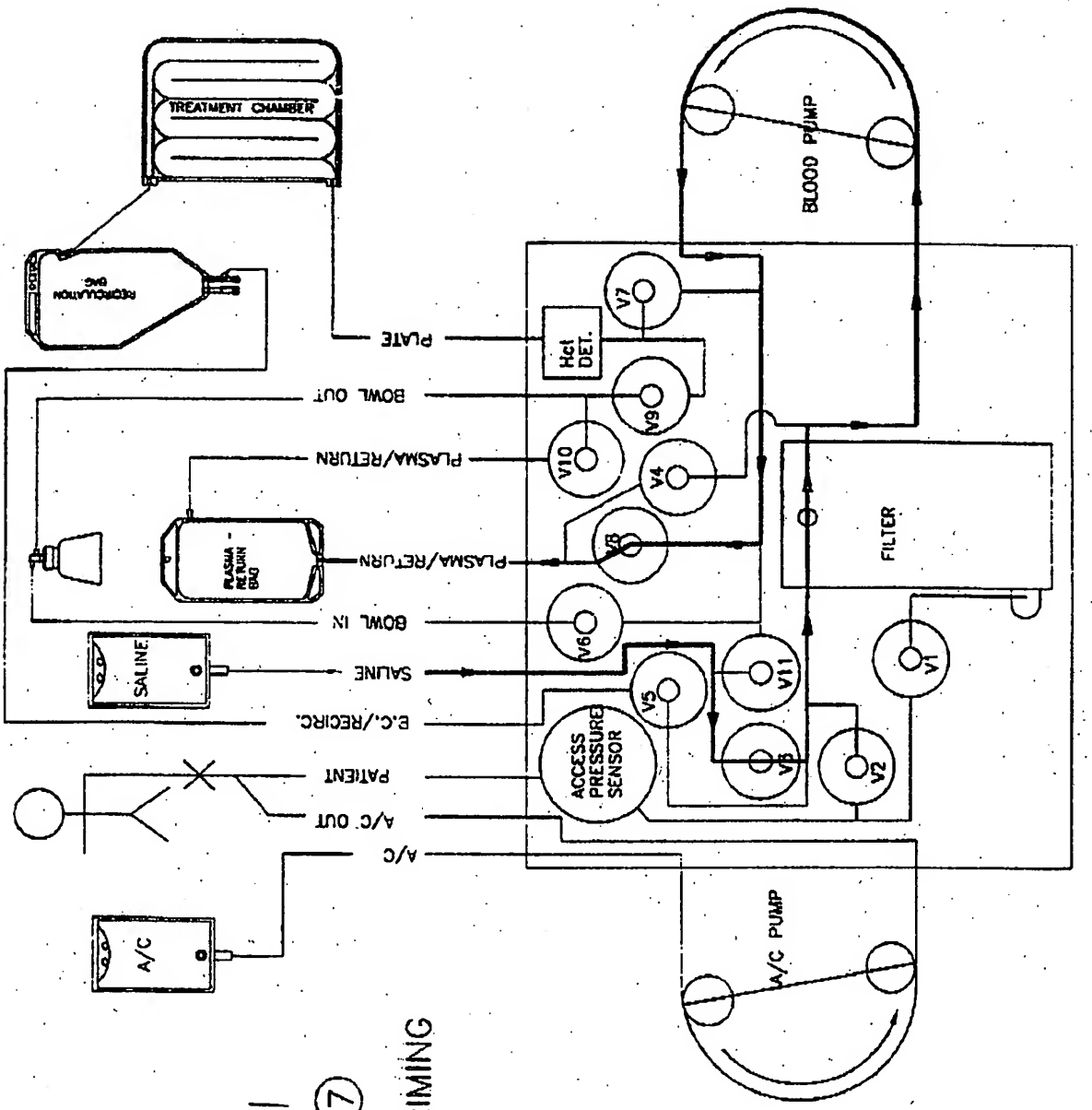


FIG 11 (7) PRIMING

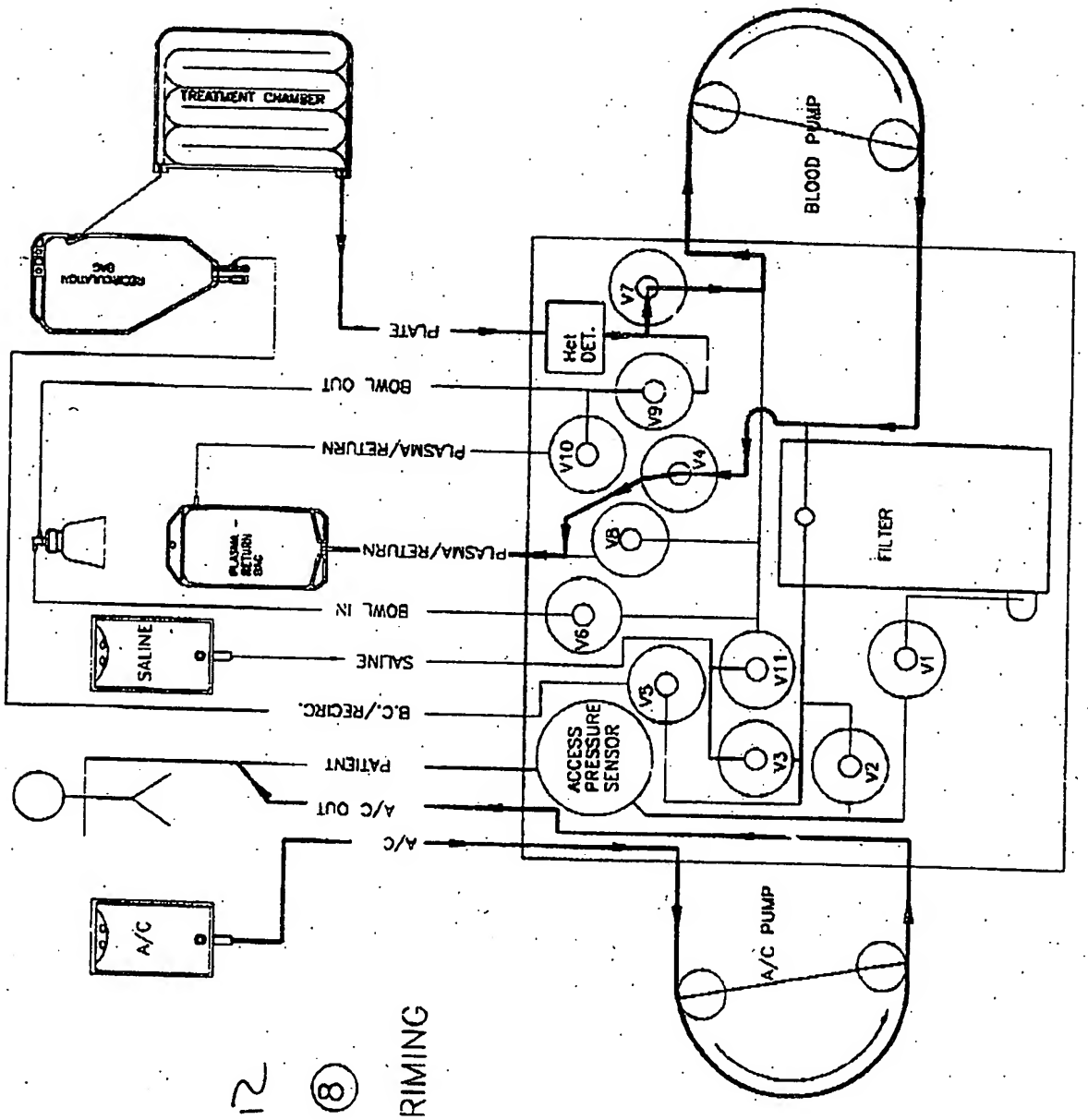
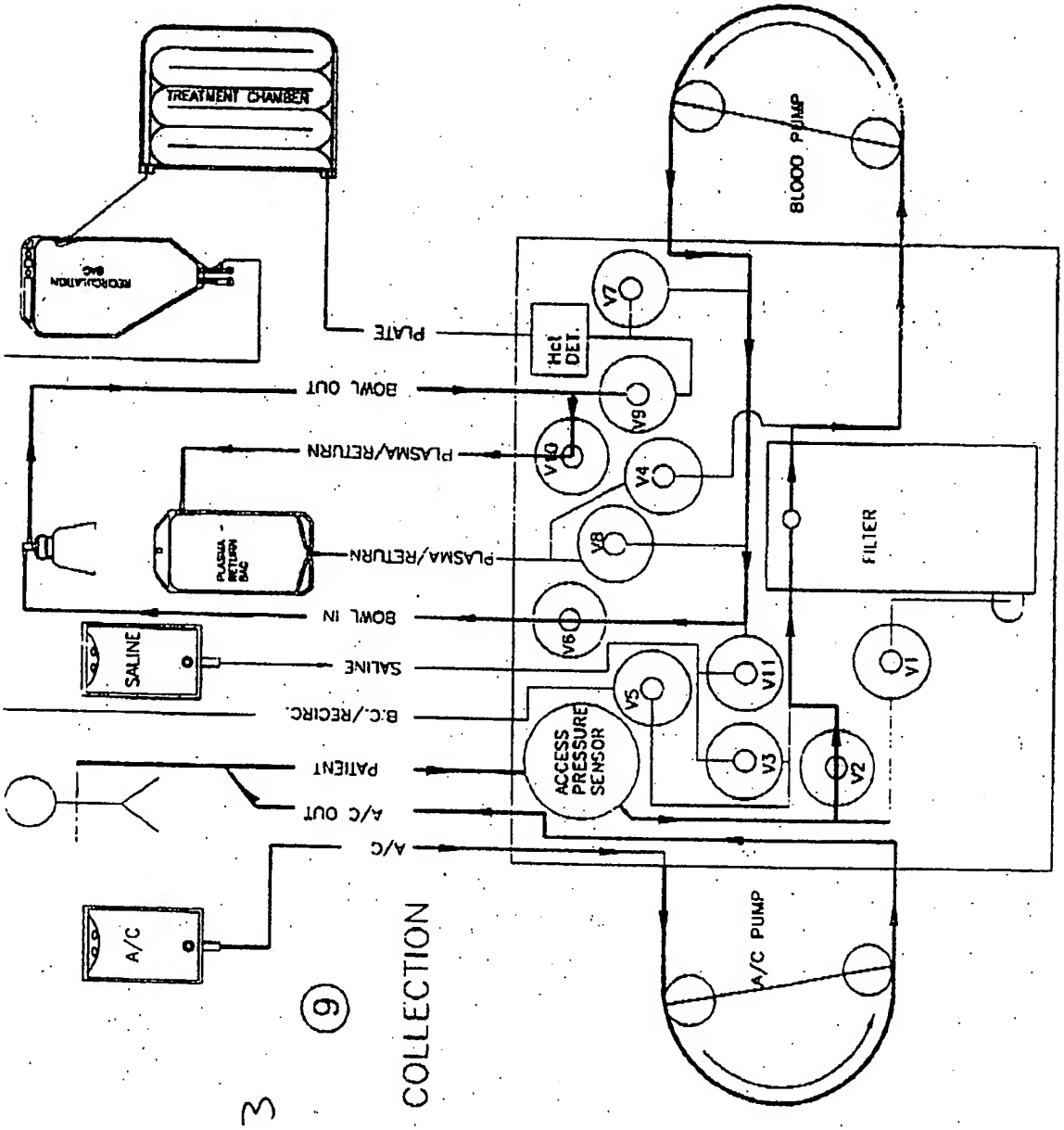


FIG. 12 ⑧ PRIMING


TREATMENT CHAMBER
BLOOD PUMP
REDISTRIBUTION BAG
PLATE
Hct DET.
V7
BOWL OUT
V9
PLASMA/RETURN
V10
V4
PLASMA RETURN BAG
PLASMA/RETURN
V8
FILTER
BOWL IN
V6
SALINE
SALINE
V11
V1
V5
B.C./RECIRC.
ACCESS PRESSURE SENSOR
V3
V2
PATIENT
A/C OUT
A/C
A/C
A/C PUMP
9
COLLECTION

F16.13

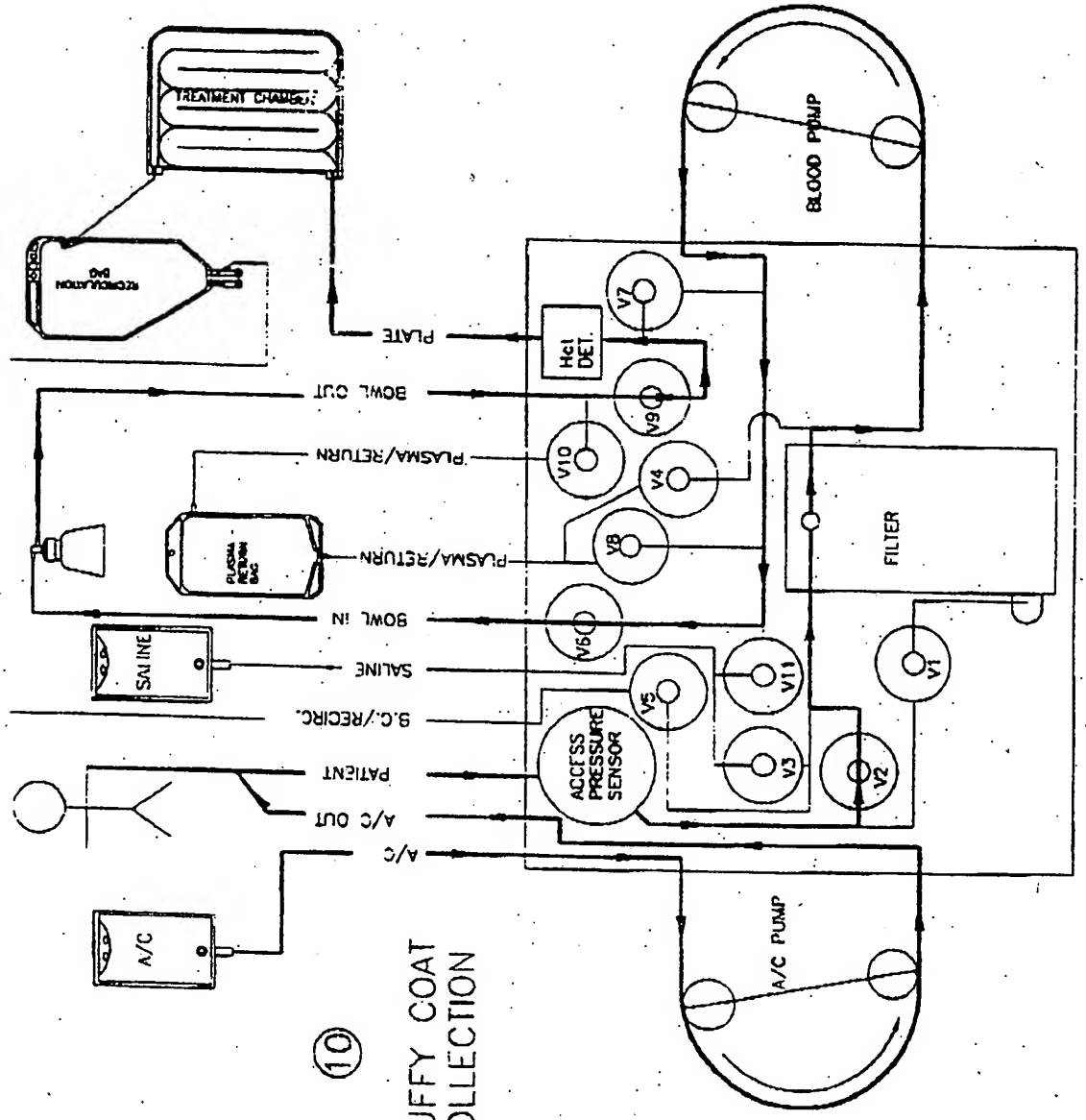


FIG. 14 (10) BUFFY COAT COLLECTION

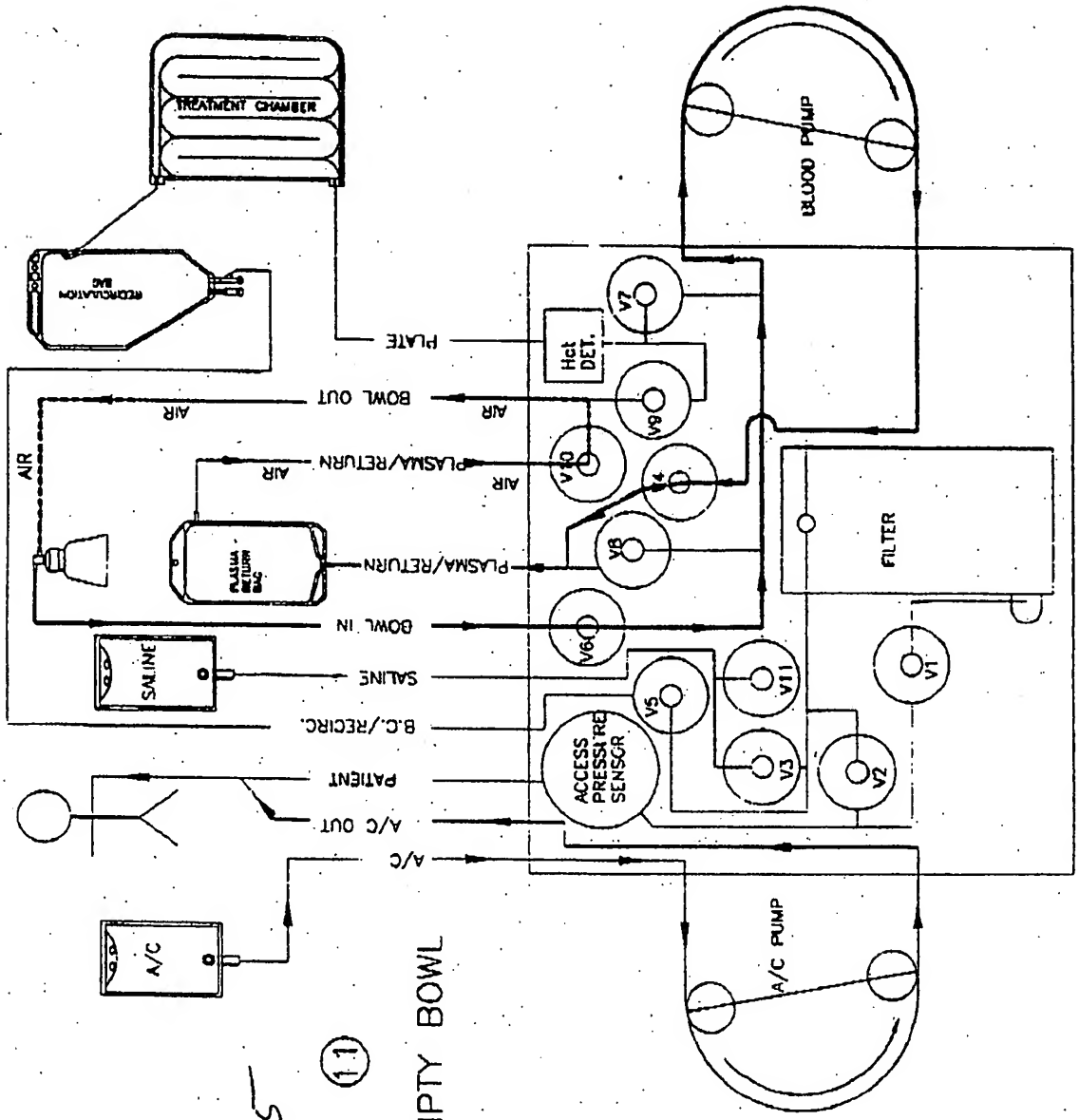


FIG. 15

(11) EMPTY BOWL

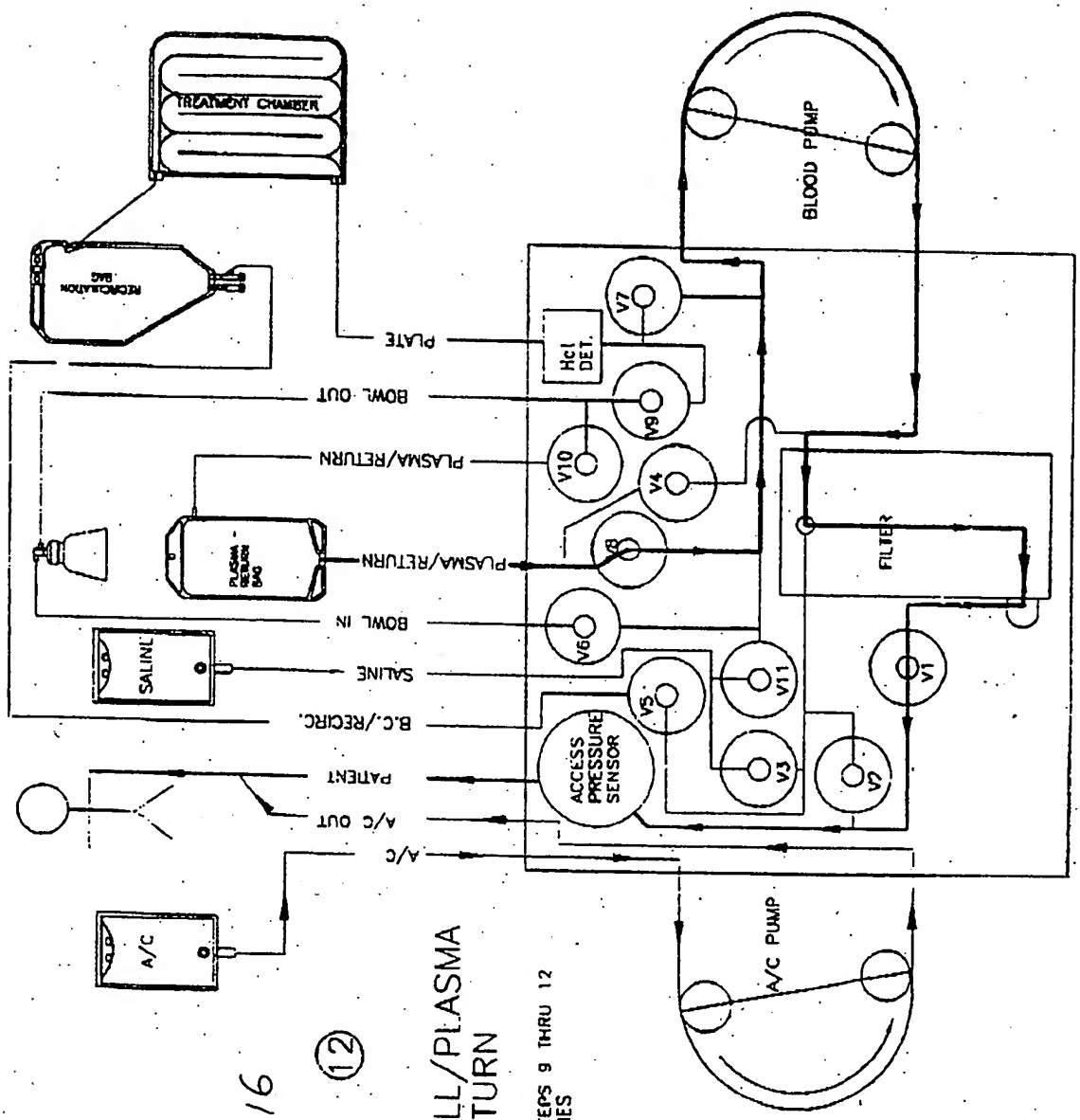

TREATMENT CHAMBER
RECIRCULATION BAG
PLATE
BOWL OUT
PLASMA/RETURN
PLASMA RETURN BAG
BOWL IN
SALINE
SALINE
B.C./RECIRC.
PATIENT
A/C OUT
A/C
A/C
BLOOD PUMP
A/C PUMP
FILTER
HCl DET.
V7
V9
V10
V4
V8
V6
V5
V11
V1
V3
V2
ACCESS PRESSURE SENSOR
RED CELL/PLASMA RETURN
REPEAT STEPS 9 THRU 12 6 TIMES
12

FIG. 16

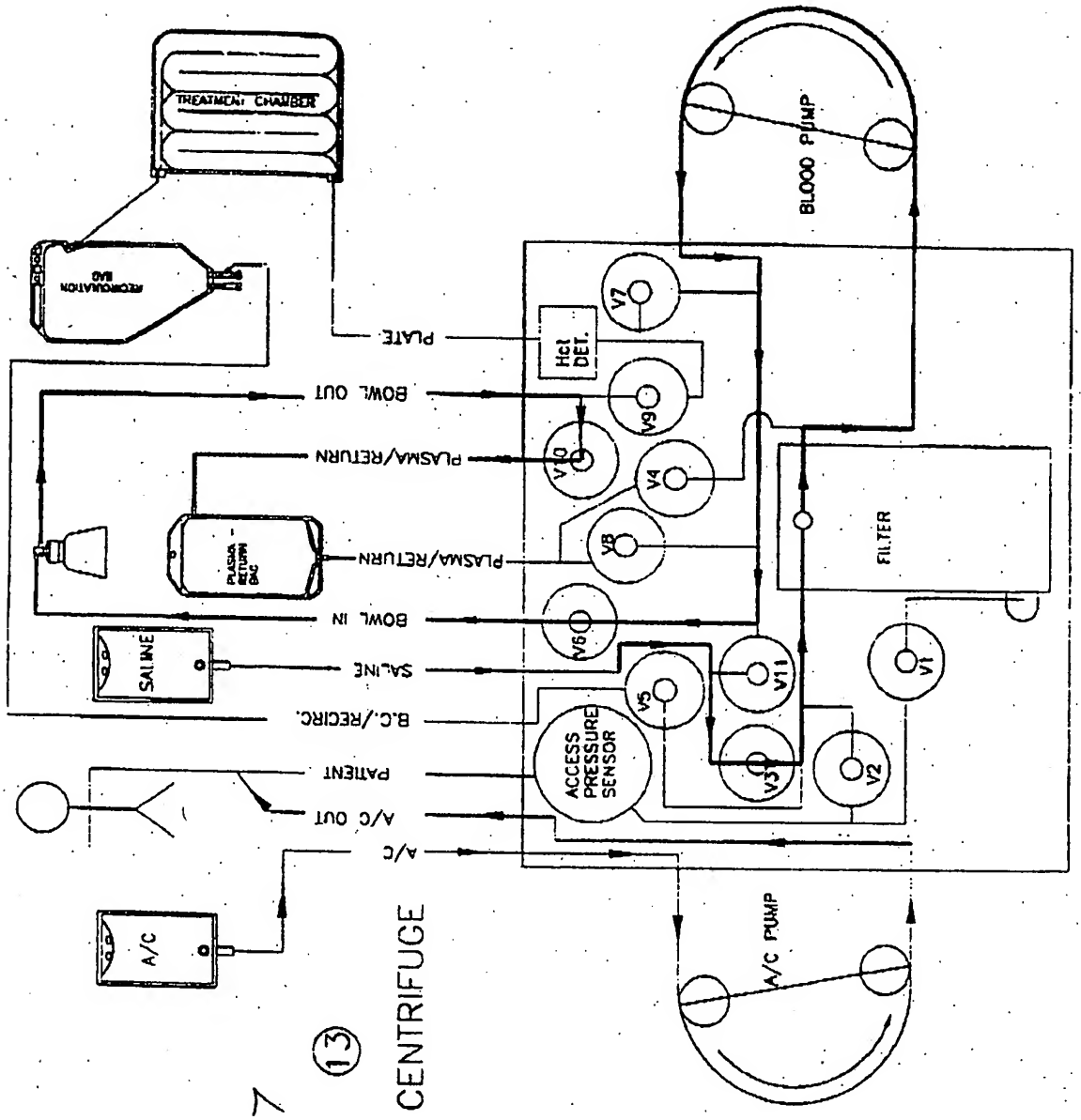


FIG. 17

(13) RINSE CENTRIFUGE

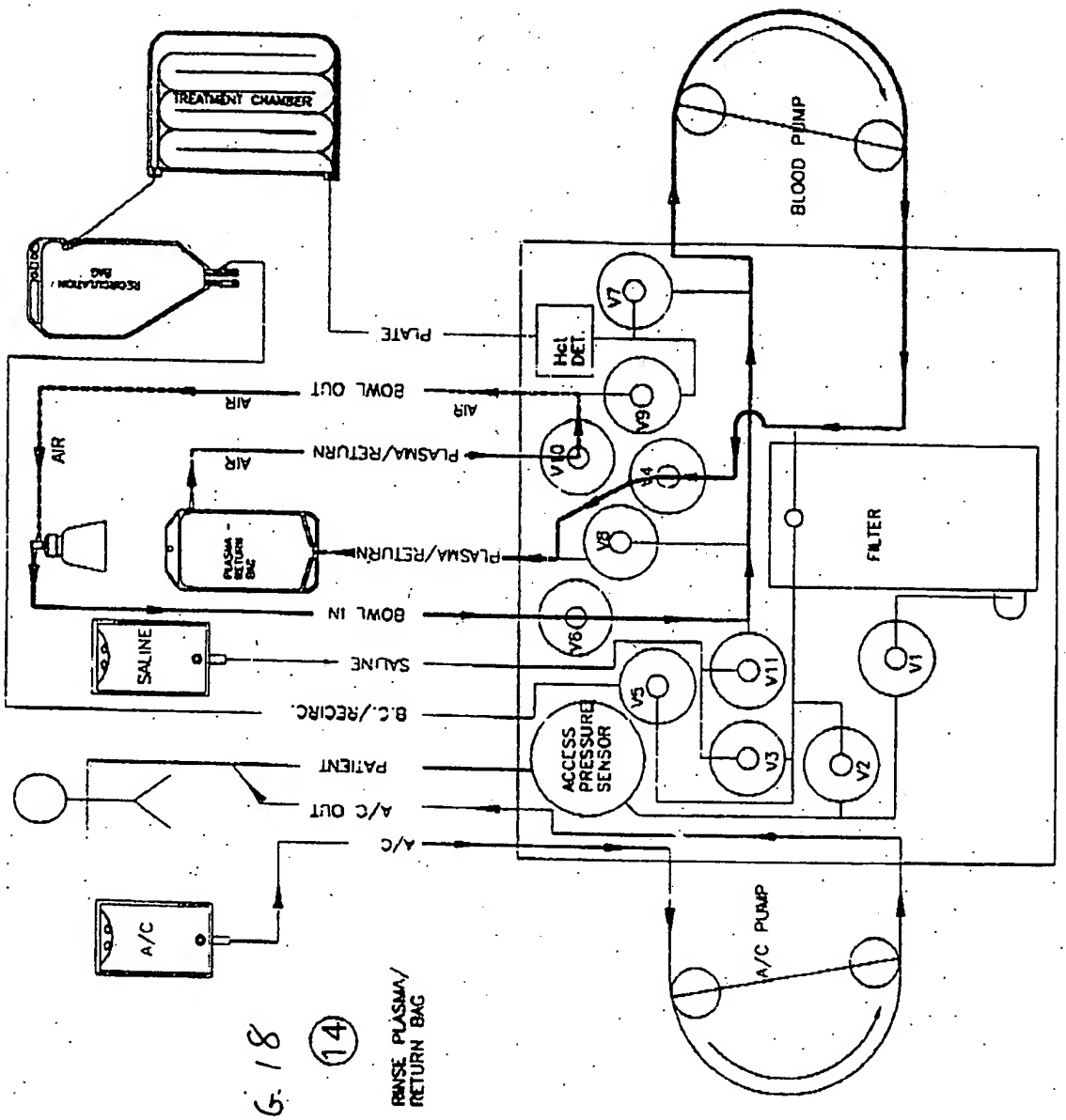

TREATMENT CHAMBER
BLOOD PUMP
FILTER
ACCESS PRESSURE SENSOR
A/C PUMP
Hct DET.
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
V11
PLATE
BOWL OUT
AIR
PLASMA/RETURN
BOWL IN
SALINE
B.C./RECIRC.
PATIENT
A/C OUT
A/C
RINSE PLASMA/ RETURN BAG

FIG. 18 (14)

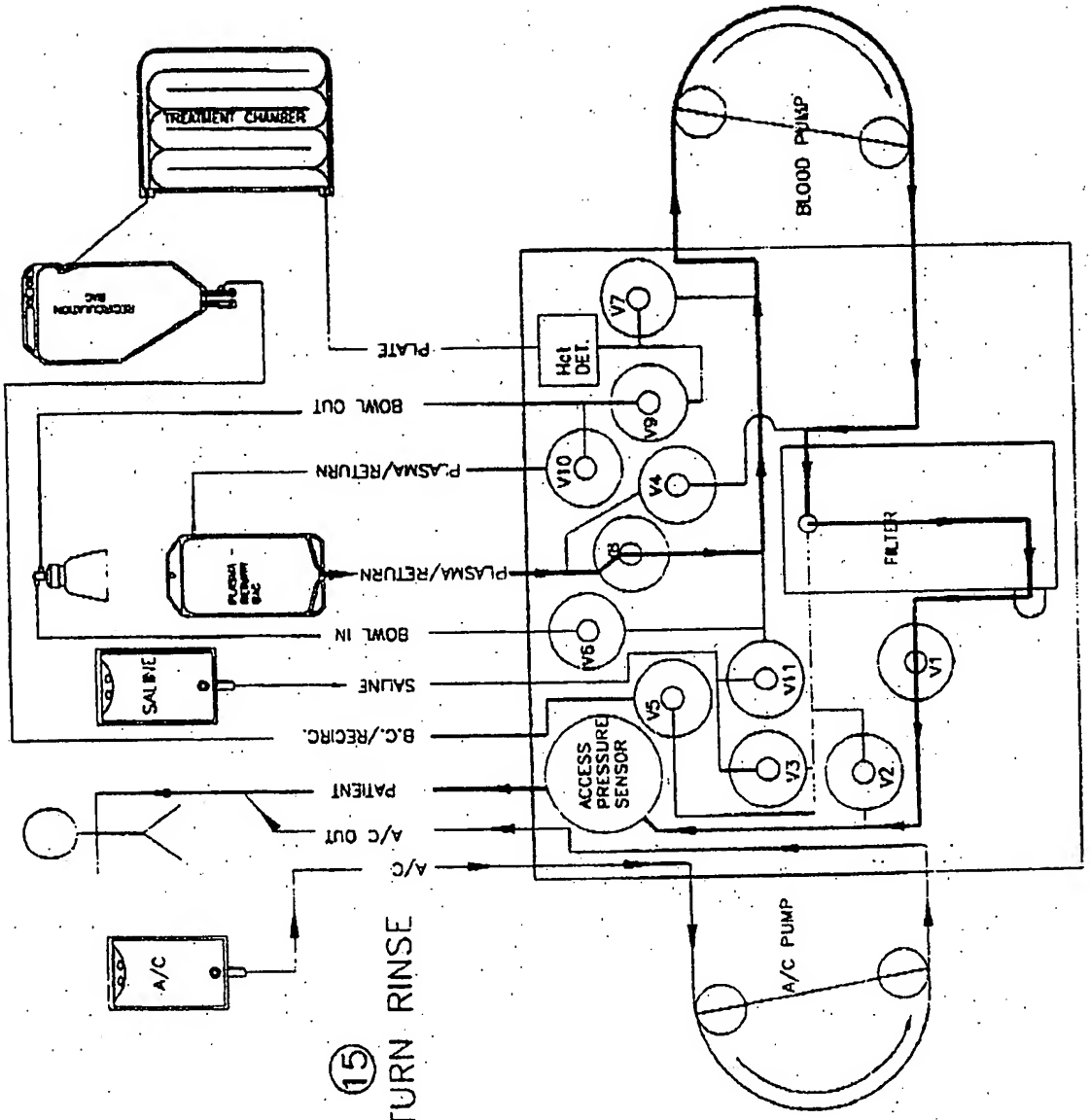


FIG. 19

(15) RETURN RINSE

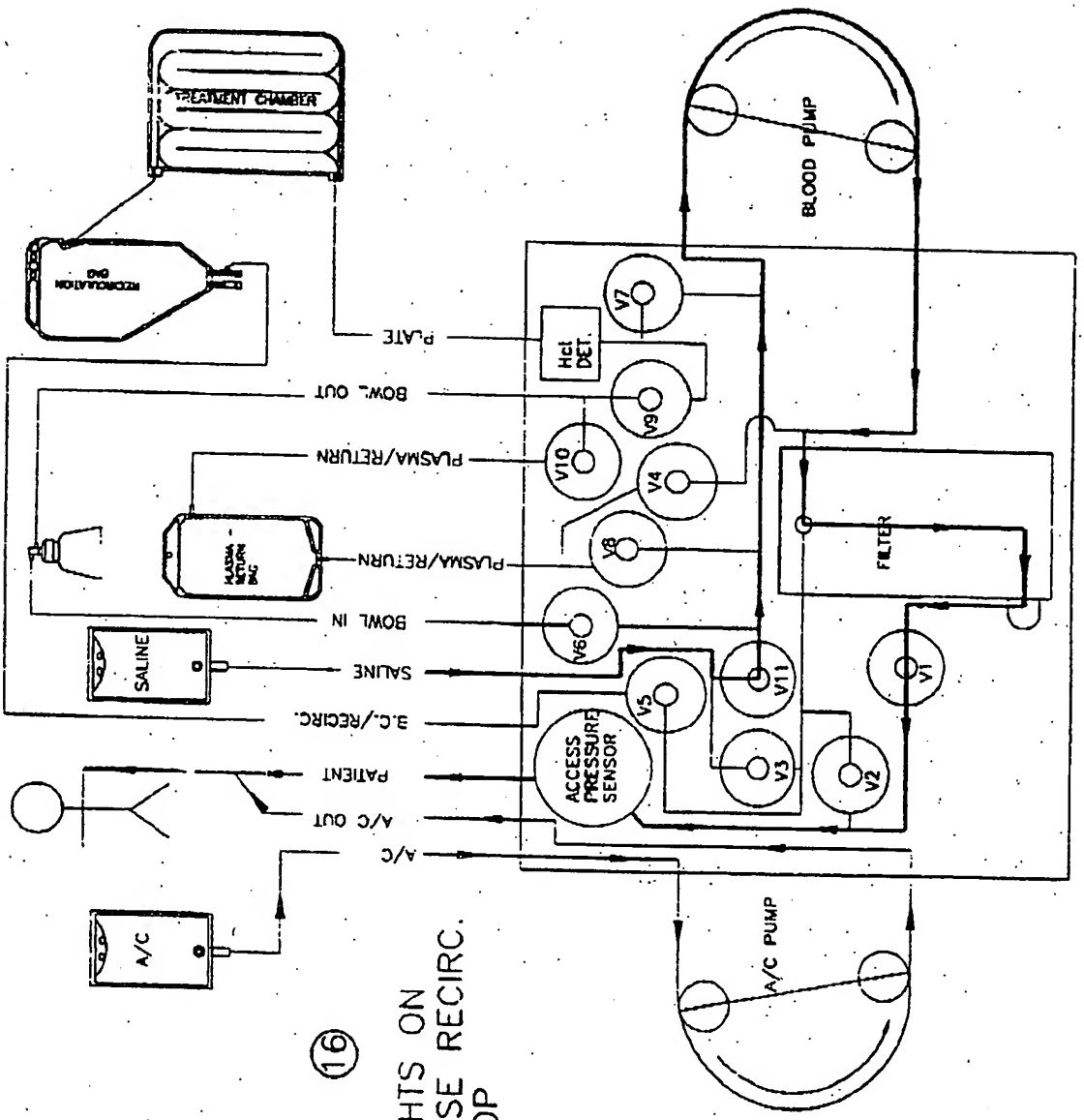


FIG. 20 (16)

LIGHTS ON
RINSE RECIRC.
LOOP

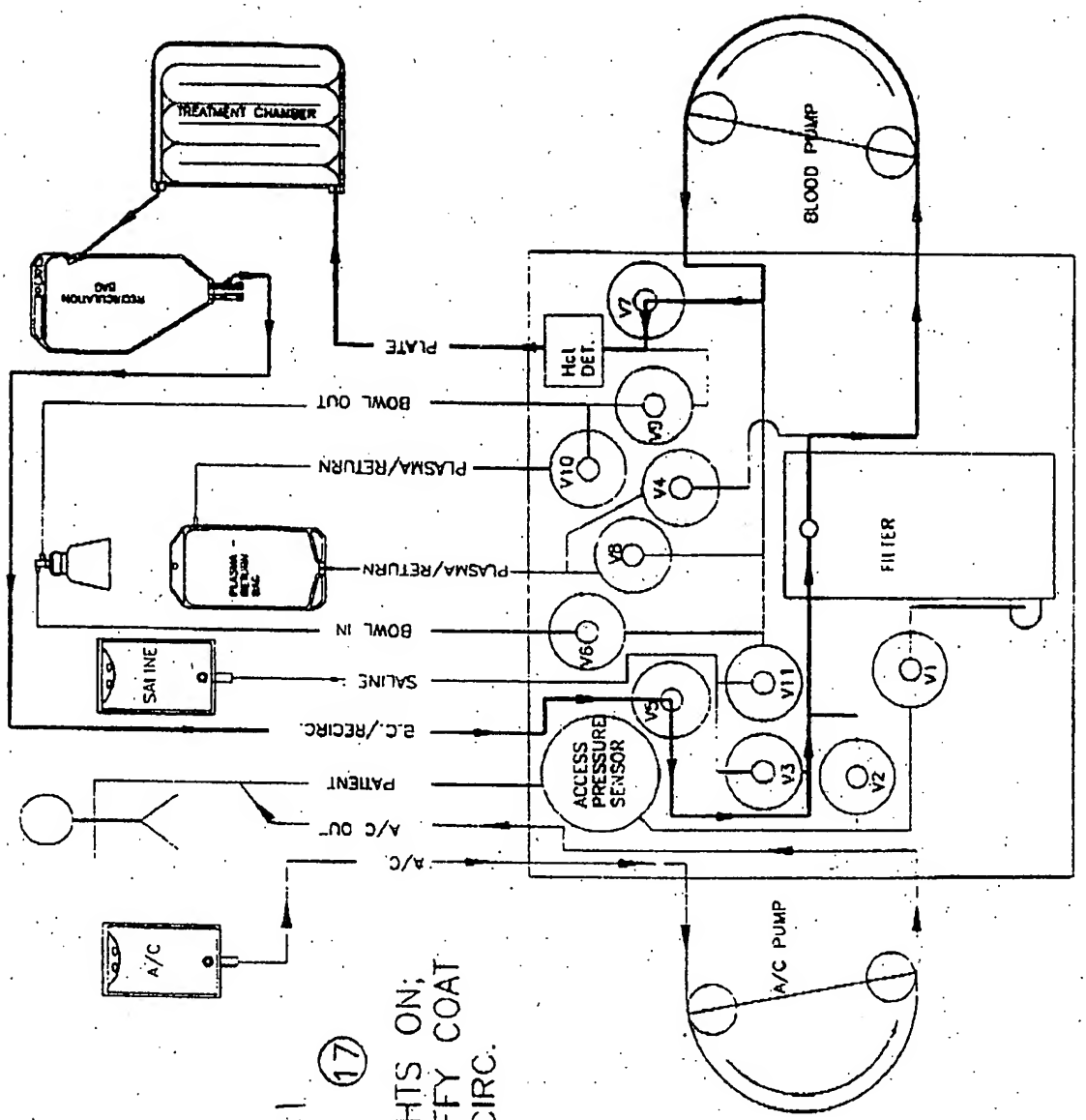


FIG. 21

(17) LIGHTS ON; BUFFY COAT RECIRC.

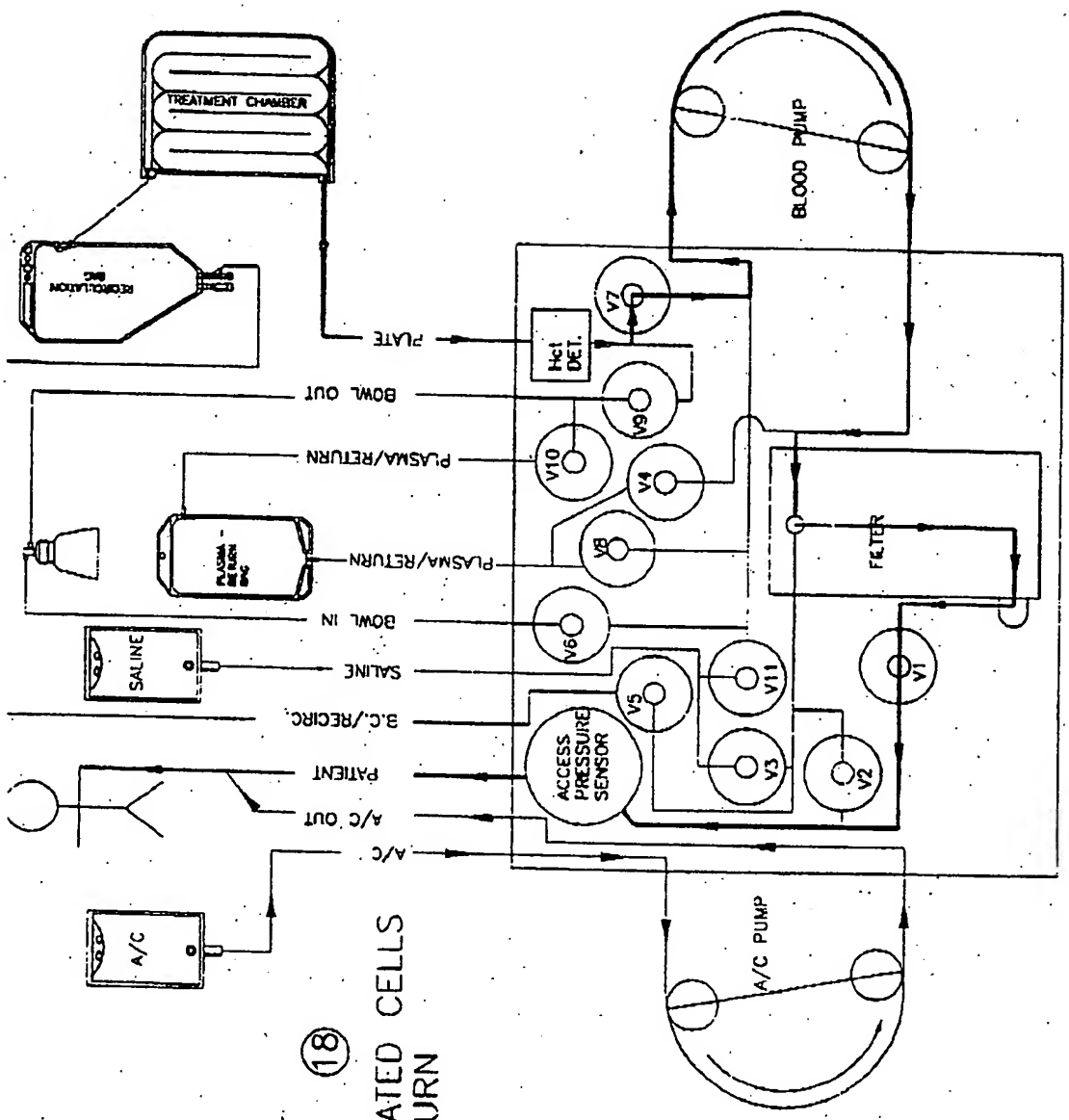

TREATMENT CHAMBER
BLOOD PUMP
FILTER
ACCESS PRESSURE SENSOR
A/C PUMP
SALINE
A/C
PLATE
BOWL OUT
PLASMA/RETURN
PLASMA/RETURN
BOWL IN
SALINE
A.C./RECIRC.
PATIENT
A/C OUT
A/C
Hct DET.
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
V11
18
TREATED CELLS RETURN

FIG. 22

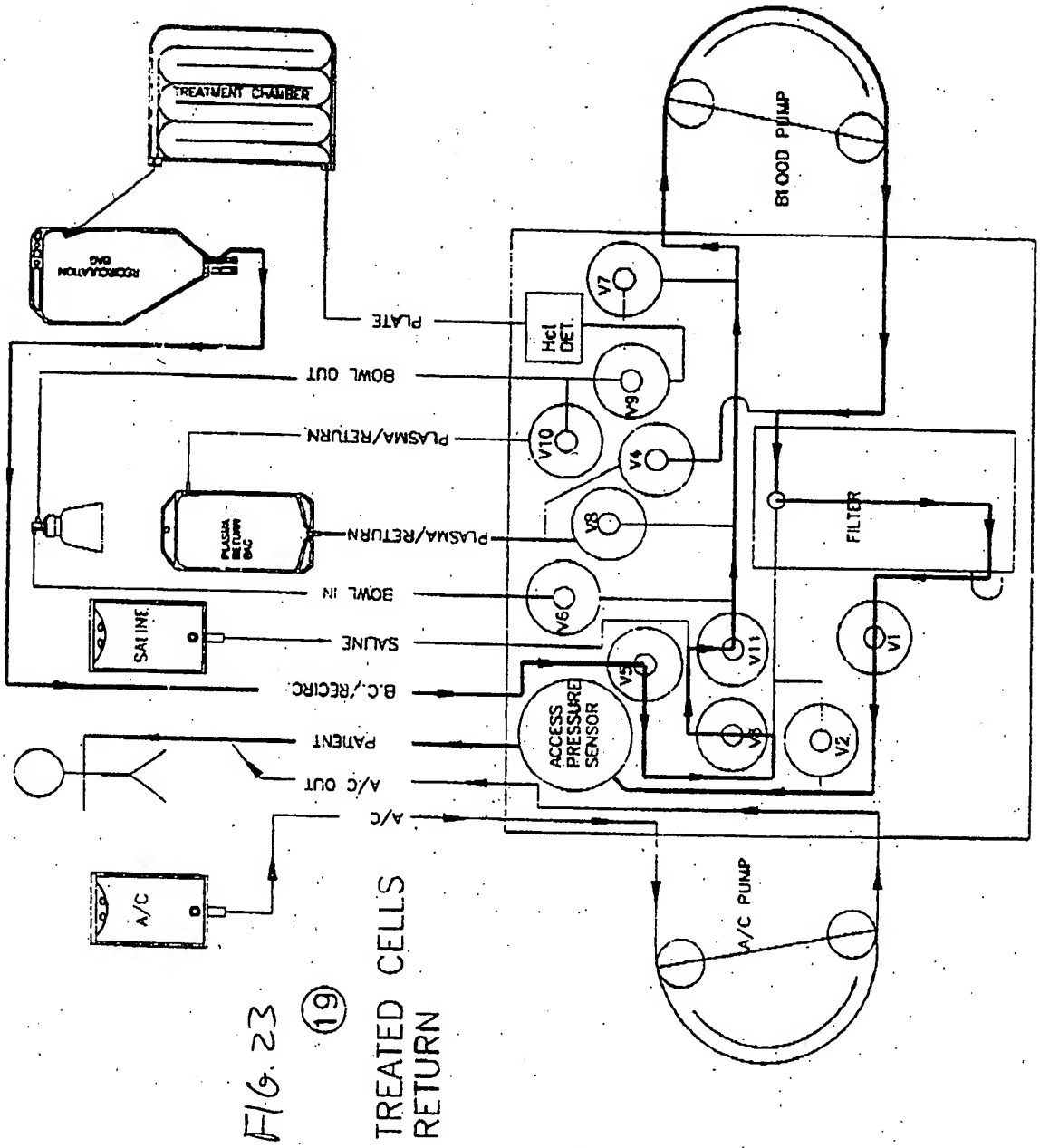


FIG. 23

(19) TREATED CELLS RETURN

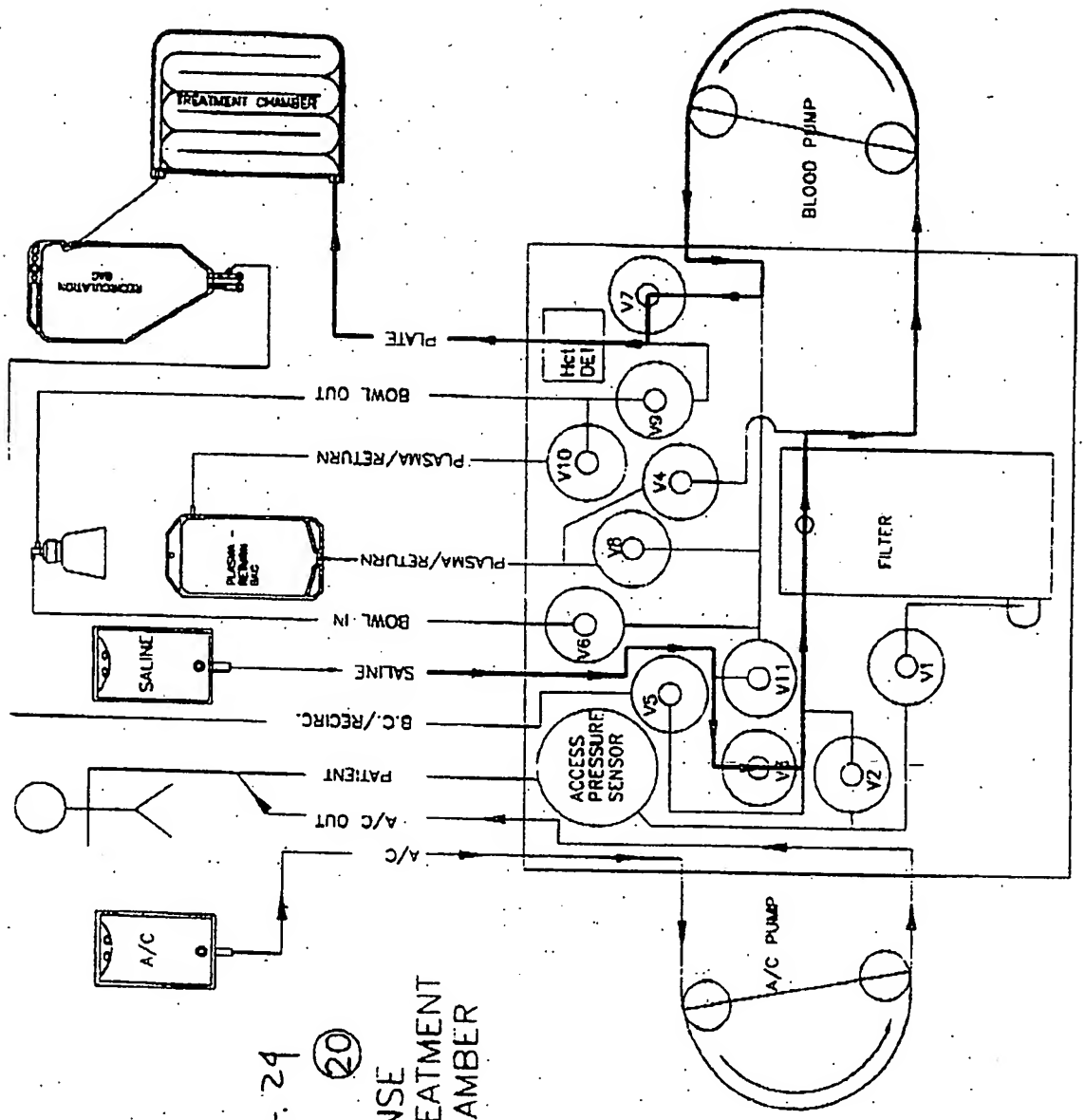


FIG. 24

(20) RINSE TREATMENT CHAMBER

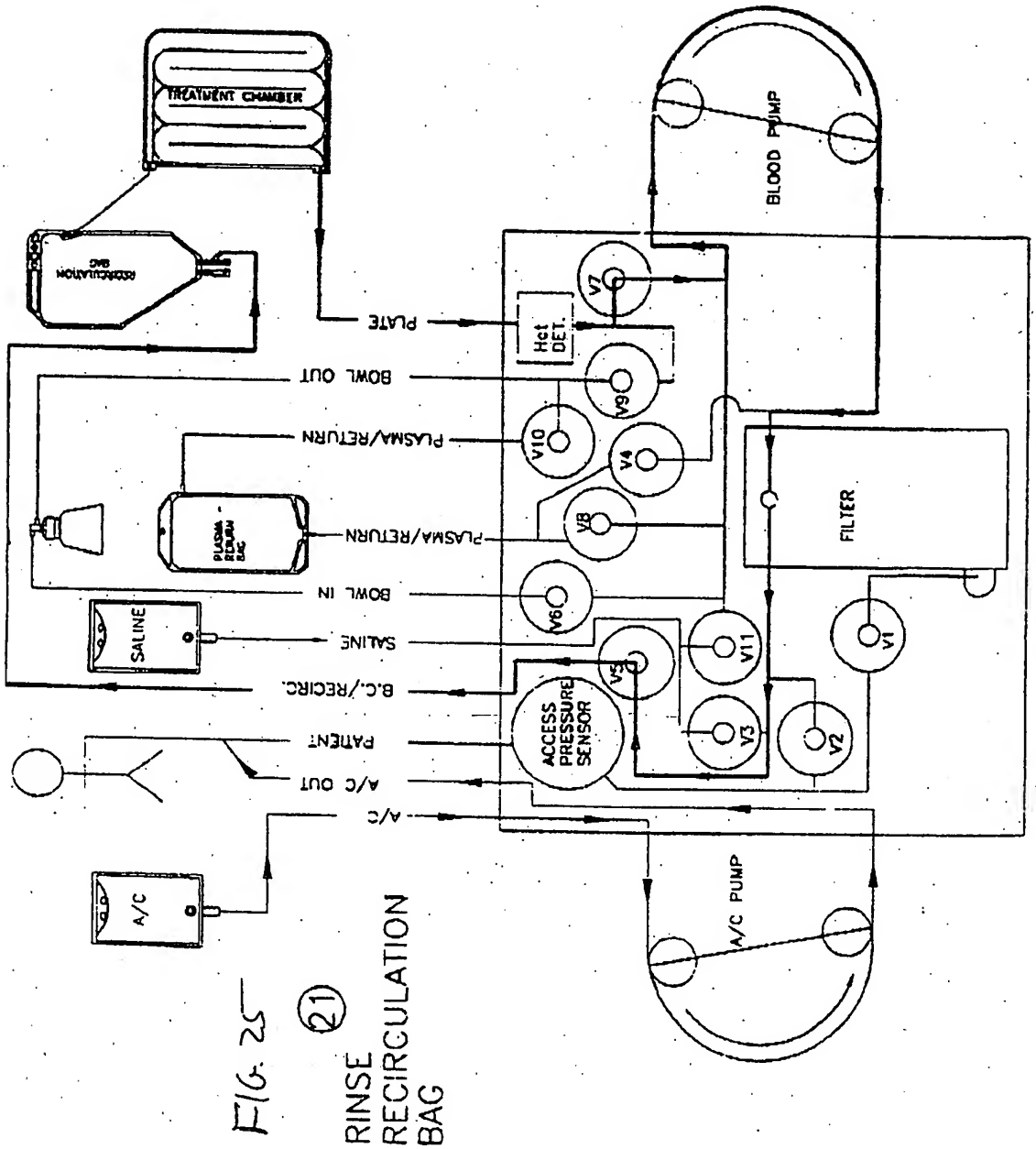


FIG. 25

(21) RINSE RECIRCULATION BAG

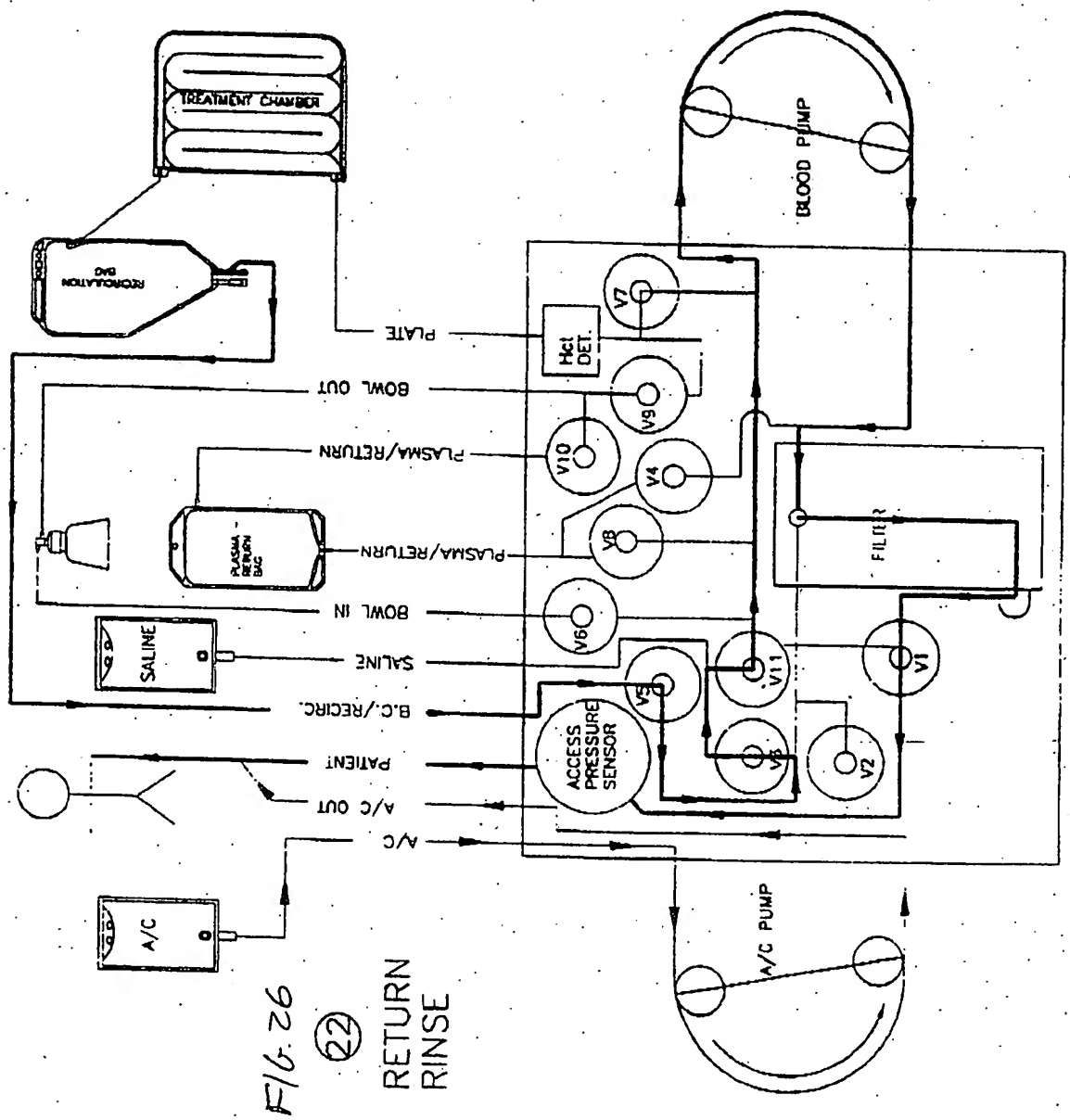


FIG. 26 (22) RETURN RINSE

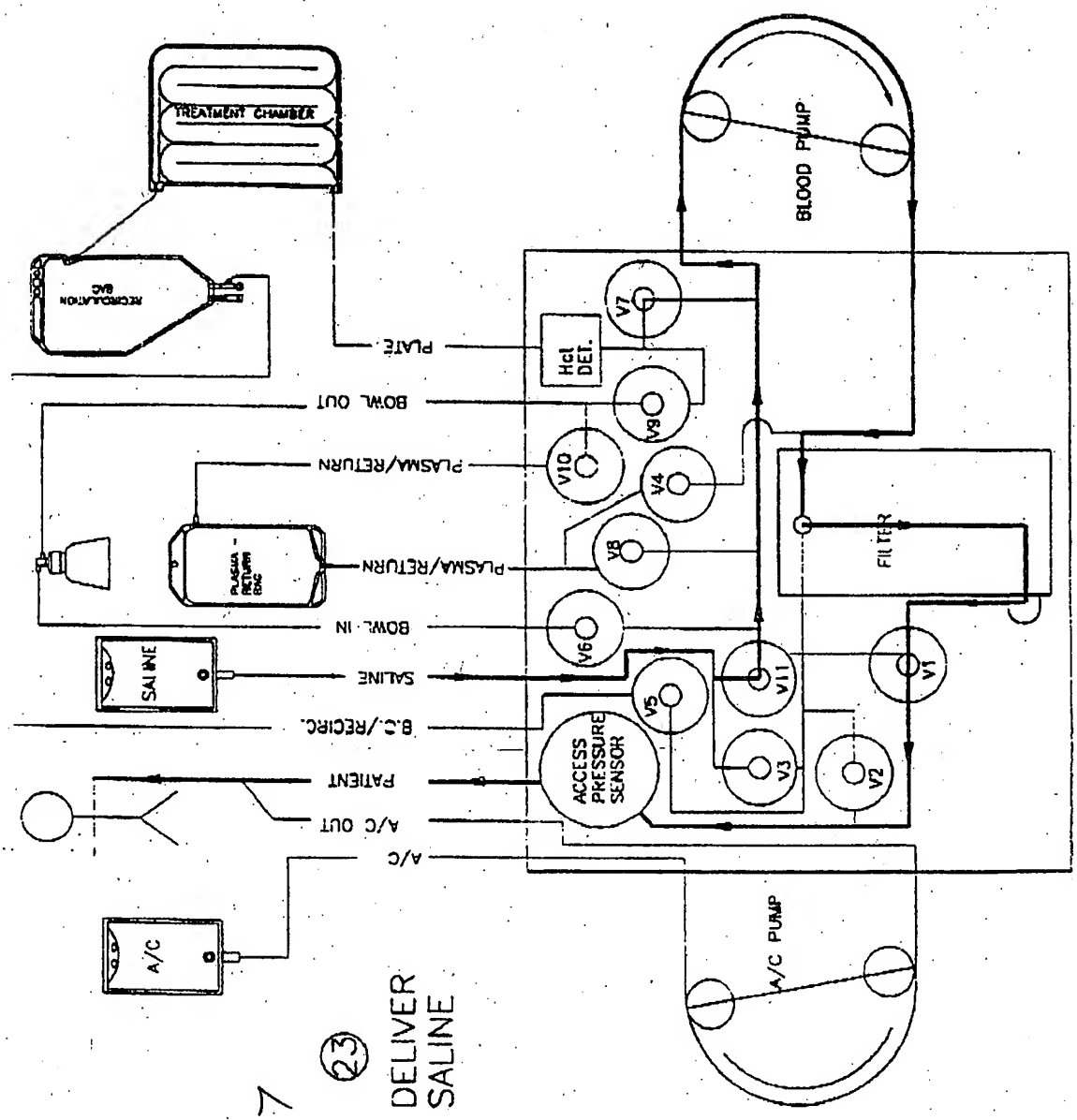


FIG. 27

(23) DELIVER SALINE

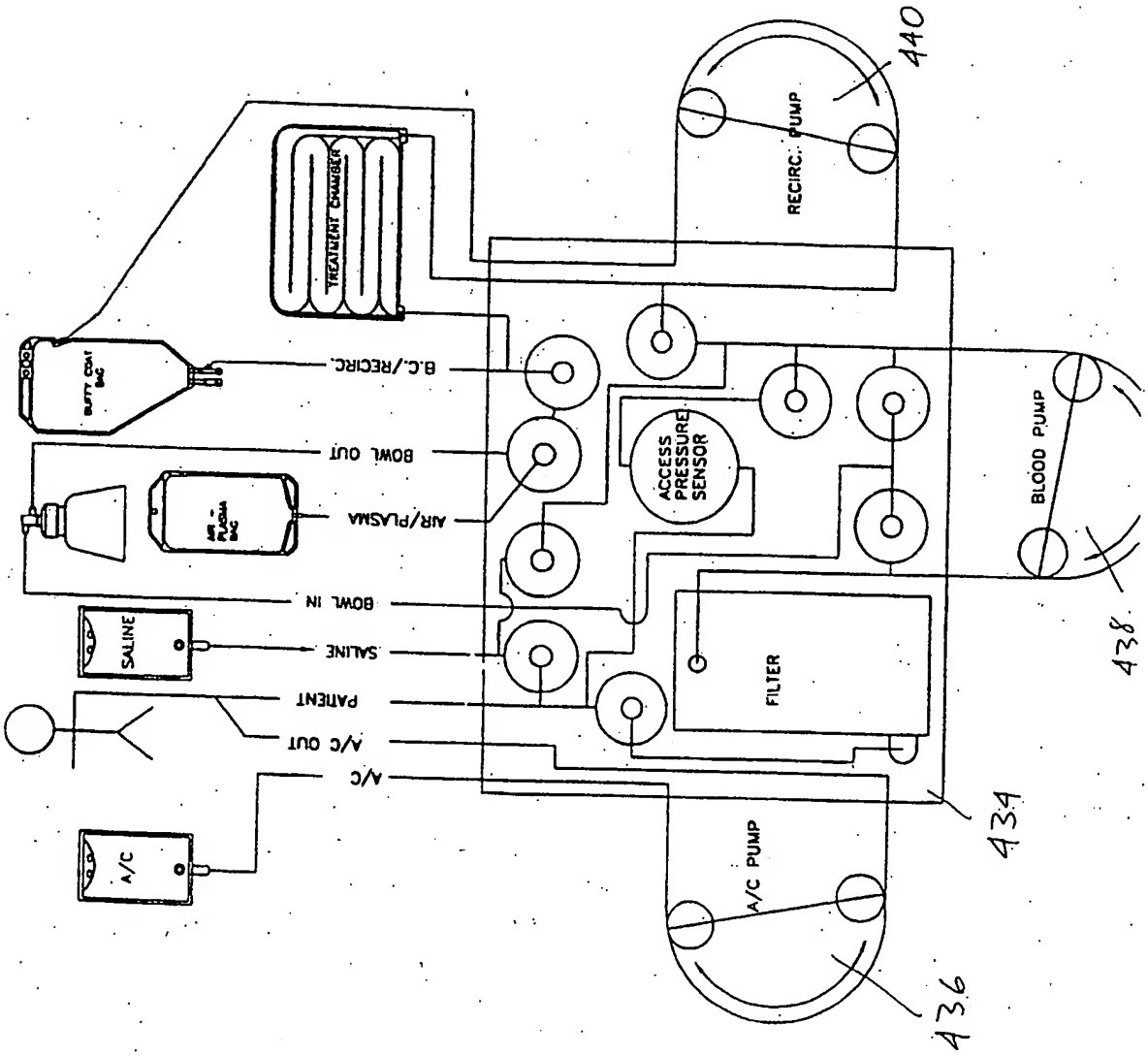

440
RECIRC. PUMP
TREATMENT CHAMBER
B.C./RECIRC.
BOWL OUT
AIR/PLASMA
BOWL IN
SALINE
PATIENT
A/C OUT
A/C
ACCESS PRESSURE SENSOR
BLOOD PUMP
438
FILTER
434
A/C PUMP
436

FIG 28

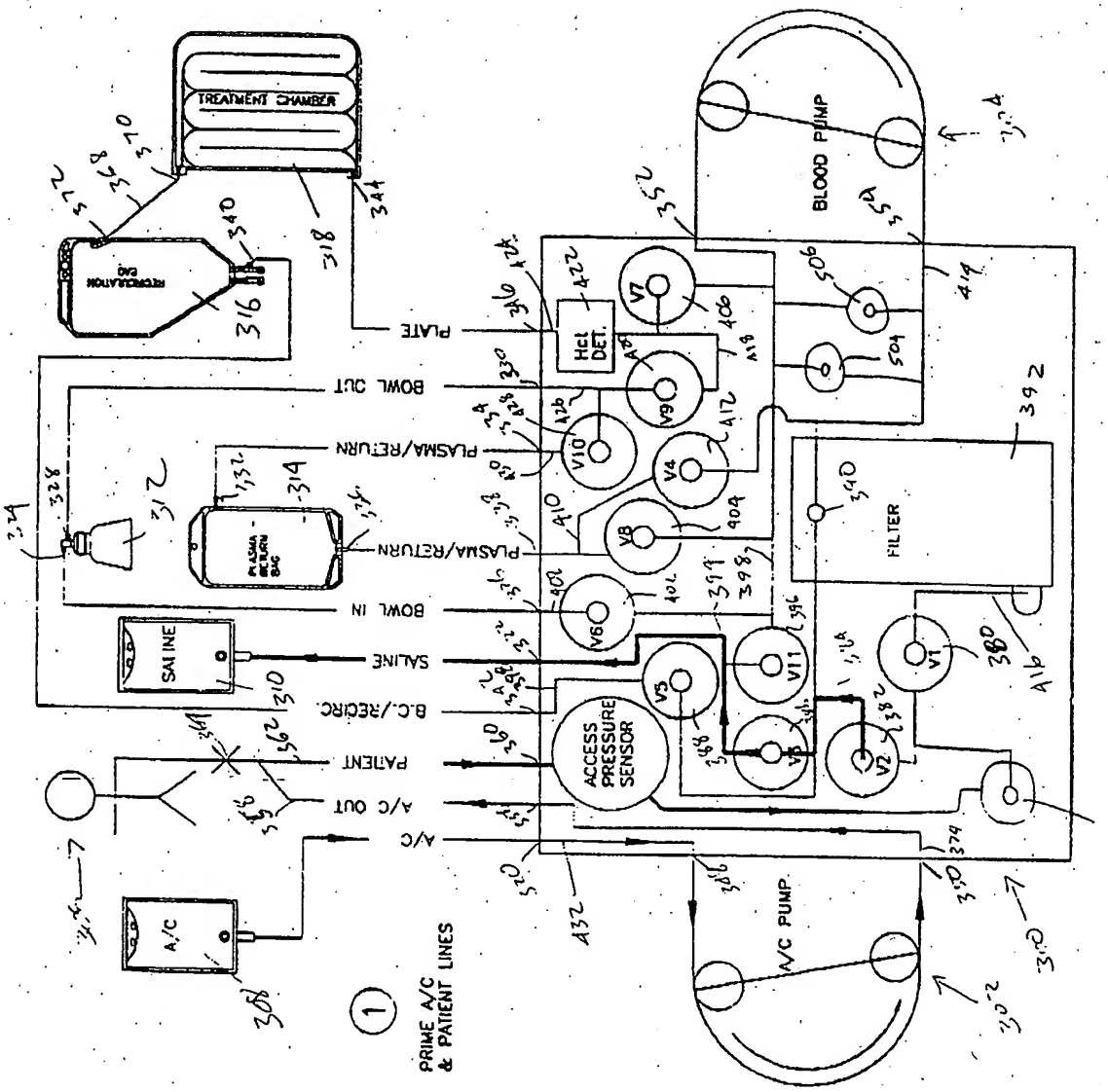
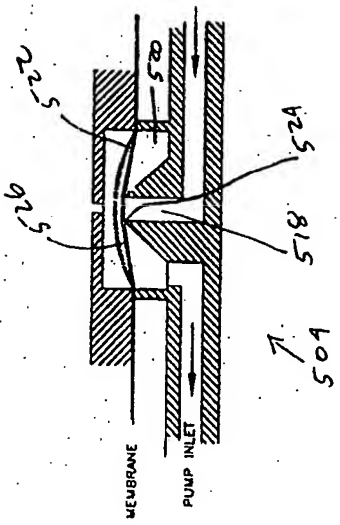
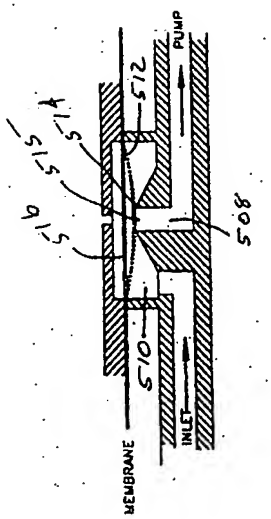

TREATMENT CHAMBER
BLOOD PUMP
A/C PUMP
FILTER
ACCESS PRESSURE SENSOR
Hct DET.
PLATE
BOWL OUT
PLASMA/RETURN
PLASMA/RETURN
BOWL IN
SALINE
B.C./RECIRC.
PATIENT
A/C OUT
A/C
SALINE
A/C
PLASMA RETURN BAG
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
V11
1
PRIME A/C & PATIENT LINES

FIG. 29



509

FIG. 31



502

FIG. 30

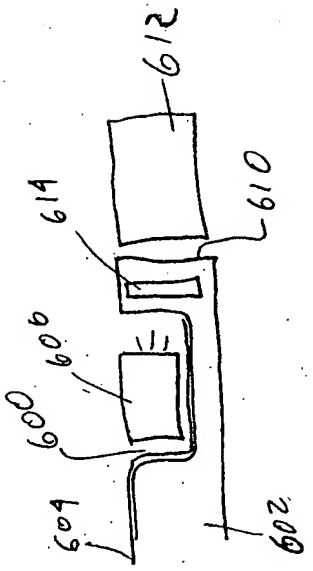

612
610
614
606
600
604
602

FIG. 33

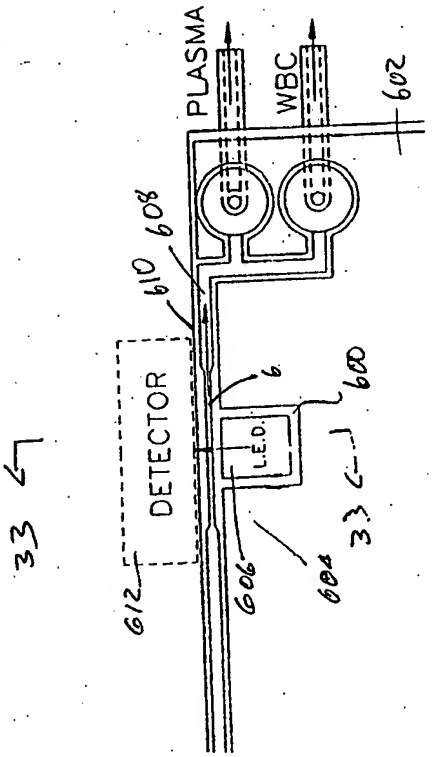

PLASMA
WBC
602
608
610
DETECTOR
L.E.D.
600
606
604
612
33

FIG. 32

INTERNATIONAL SEARCH REPORT

Internat. Application No
PCT/US 97/21267

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61M1/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 93 00941 A (HAEMONETICS CORP.) 21 January 1993 see page 7, line 15 - page 8, line 17 see figures 1,3,9 ---	1
X	FR 2 513 884 A (ELMAR MEDICAL SYSTEMS LTD) 8 April 1983 see page 5, line 9 - page 7, line 1 see page 8, line 24 - page 10, line 3 see page 10, line 32 - page 11, line 10 see figures 2,3,6	1
A	---	2
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 March 1998	17.04.1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Vereecke, A

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Internal Application No
PCT/US 97/21267

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 93 15777 A (ALCON SURGICAL INC.) 19 August 1993 see page 1, line 21 - line 32 see page 10, line 4 - line 19 see figures 4,9-11	1
A	---	2
Y	WO 84 02473 A (BAXTER TRAVENOL LABORATORIES INC) 5 July 1984 see page 16, line 20 - page 17, line 25 see page 20, line 24 - line 29 see figures	16
Y	---	16
	FR 2 560 770 A (CHEVAL MARGUERITE) 13 September 1985 see the whole document	
A	---	1,2
	GB 2 176 717 A (COBE LABORATORIES INC.) 7 January 1987 see page 2, line 22 - line 28 see figure 1	
A	---	16
	GB 1 492 386 A (E LICHTENSTEIN) 16 November 1977 see page 7, line 31 - line 110 see figures	
A	---	16
	US 5 354 268 A (PETERSON ERIK W ET AL) 11 October 1994	

1

INTERNATIONAL SEARCH REPORT

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PCT/US 97/21267

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		AU 3218293 A	12-08-93
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		DE 69309757 T	28-08-97
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		DE 3378612 A	12-01-89
		EP 0129554 A	02-01-85
FR 2560770 A	13-09-85	NONE	
GB 2176717 A	07-01-87	US 4666598 A	19-05-87
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		GB 2208714 A,B	12-04-89
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		JP 4057349 B	11-09-92
		JP 62005355 A	12-01-87

INTERNATIONAL SEARCH REPORT

Information on patent family members

Internat. Application No
PCT/US 97/21267

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		AU 7300574 A	11-03-76
		CA 1034459 A	11-07-78
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		DE 2442086 A	20-03-75
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		SE 8200621 A	03-02-82
		US 4370983 A	01-02-83
US 5354268 A	11-10-94	US 5520652 A	28-05-96

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 643 808 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
14.01.1998 Bulletin 1998/03

(51) Int Cl.6: **F04B 43/12**, F04B 43/00, F04B 11/00

(21) Application number: **93914211.3**

(86) International application number:
PCT/US93/05064

(22) Date of filing: **27.05.1993**

(87) International publication number:
WO 93/24755 (09.12.1993 Gazette 1993/29)

(54) REDUCED PULSATION TAPERED RAMP PUMP HEAD

PUMPENKOPF MIT VERJÜNGENDER RAMPE ZUR PULSATIONSREDUZIERUNG

POMPE A ELEMENT CONIQUE OFFRANT UNE PRESSION DE REFOULEMENT A PULSATION REDUITE

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(73) Proprietor: **ALLERGAN, INC.**
Irvine, California 92713-9534 (US)

(72) Inventors:
- **ZANGER, Frank**
  Hayward, CA 94541 (US)
- **SURBER, Tim**
  San Leandro, CA 94578 (US)
- **ROSLON, Susanne**
  Laguna Niguel, CA 92677 (US)

(74) Representative: **Hutchins, Michael Richard et al**
FRY HEATH & SPENCE
The Old College
53 High Street
Horley Surrey RH6 7BN (GB)

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- **PISULA 'tubing for peristaltic pumps' 26 May 1988 , MACHINE DESIGN , CLEVELAND**

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Description

The present invention generally relates to peristaltic pumps and more particularly to precision peristaltic pumps, particularly suitable for the simultaneous removal (aspiration) of irrigation fluids in an eye cavity during ophthalmic surgery as, for example, for the removal of cataracts.

The necessity for precisely controlling pressure in the eye during surgery is well-known. During surgery on normally pressurized eyes, instruments are passed through a small incision of the cornea in order to access and remove a natural lens which has become opaque from a cataract.

Cataracteous lens may be broken up by cutting apparatus or by ultrasonic apparatus and the fractured material aspirated, together with a quantity of aqueous irrigation fluid in the eye chamber.

The removed irrigation fluid is simultaneously replaced in order to maintain a normal pressure in the eye.

While pressure may be controlled by a pressure regulation device, greater pressure stability nay be assured through the use of a pump having minimal back pressure or pump pulsations.

Severe reductions in the eye pressure will result in collapse of the eye chamber, but aside from these traumatic results, the maintenance of proper pressure within an eye during surgical procedures is important to preserve and stabilize the spatial relationships of the intraocular tissues. Thus, variations of pressure during an operation may impair the surgeon's ability to observe and operate on intraocular tissues.

Peristaltic pumps having the features set forth in the preamble to claim 1 appended hereto are disclosed in EP-A-0 019 818 in the name of Siemens.

The present invention provides a peristaltic pump having significantly reduced pump pulsations and therefore particularly suitable for use in surgical procedures such as those hereinabove described.

SUMMARY OF THE INVENTION

A peristaltic pump in accordance with the present invention has the features set forth in claim 1 below.

A peristaltic pump in accordance with the present invention includes a plurality of tube compression means for compressing and sealing a collapsible and resilient tube. Housing means is provided for guiding the collapsible and resilient tube to and from the tube compression means and means are provided for causing the plurality of tube compression means to successively contact, gradually compress and seal the compressible and resilient tube and thereafter gradually uncompress the tube in order to move a fluid through the tube in one direction without creating substantial fluid back pressure in the opposite direction.

More particularly, the plurality of tube compression means comprise a plurality of rollers and the means for causing the plurality of tube compression means to contact, compress and seal the tube comprises a pump arm, having an arcuate surface, and mounted to the housing means in a position enabling the rollers to contact, compress and seal the tube.

Still more particularly, the peristaltic pump in accordance with the present invention further includes assembly head means for supporting the plurality of rollers in a circular pattern about an assembly head axis with each roller having a rotation axis generally parallel to the assembly head axis.

Specifically, the arcuate surface is configured and the pump arm position with respect to the assembly head so that as the assembly head is rotated, each roller successively contacts the tube, gradually compresses and seals the tube during an approximate 45° rotation of the assembly head. Additionally, the arcuate surface is configured with the pump arm position with respect to the assembly head so that each roller successively releases the tube during a rotation of the assembly head about 45°.

The arcuate surface is configured and the pump arm positioned with respect to the assembly head so that each roller maintains a sealing engagement with the tube during approximately a 45° rotation of the assembly head.

In order for uniformly sealing the tube as the roller compresses the tubing, each roller includes a specific circumferential surface thereon. Particularly, each roller has an inside diameter that is smaller than a roller diameter at each end of the roller, and this smaller diameter may be constant between end diameters on each roller, with the end diameters interconnected with the constant diameter by an arcuate surface.

In combination, the present invention also includes a collapsible resilient tube which includes means for preventing movement of the tube itself through the housing means. Particularly, the means for preventing movement of the tube may include at least one collar disposed on the tube having a diameter sufficient to prevent entry of the collar into the housing means.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages and features of the present invention will be better understood by the following description when considered in conjunction with the accompanying drawings in which:

Figure 1 is a perspective view of an assembled peristaltic pump in accordance with the present invention;

Figure 2 is a perspective exploded view of the peristaltic pump shown in Figure 1;

Figure 3 is a cross-section view of the peristaltic pump in accordance with the present invention

showing a plurality of rollers for compressing a resilient tube against a pump arm arcuate surface;

Figure 4 is a cross-section of a prior art peristaltic pump showing the relationship between the rollers and the pump arm arcuate surface;

Figure 5 is a cross-section view of a roller in accordance with the present invention taken along the line 5-5 shown in Figure 3;

Figure 5a is a cross-section veiw of a prior art roller for a peristaltic pump showing incomplete sealing of a tube;

Figure 6 is a plot of vacuum pressure as a function of time for both a prior art peristaltic pump and a peristaltic pump in accordance with the present invention, showing in comparison a significant reduction in back pressure during operation of the peristaltic pump made in accordance with the present invention operating at flow rate of about 10 ccs per minute; and

Figure 7 is a plot similar to the plot shown in Figure 6 showing the vacuum as a function of time for both prior art pumps and a pump in accordance with the present invention at a flow rate of about 40 ccs per minute.

DETAILED DESCRIPTION OF THE DRAWINGS

Turning now to Figures 1 and 2, there is shown a peristaltic pump 10 in accordance with the present invention generally including an assembly head 26 which provides a means for supporting a plurality of rollers 28 with the latter providing compression means for compressing and sealing a collapsible and resilient tube 32 against an arcuate surface 34 on a pump arm 36.

The pump arm 36 is pivotally mounted to a housing 40 by means of a pin 42 and washer 44 for enabling movement thereof to facilitate insertion and removal of the tube 32. Apertures 46 48 in the housing 40 enable the housing to provide means for guiding the collapsible and resilient tube 32 to and from the arcuate surface 34 and rollers 28.

A spring 52 loaded latch 54 pivotally mounted to the pump arm 36 by a pin 55 enables locking of the pump arm 36 to the housing after insertion of the tube 32 through the apertures 46 and 48, and during operation of the pump. This locking is enabled by the tongue 56 which snaps over a recess 58 in the housing 40, securing a front housing wall 60 between the tongue 56 and a rear portion 62 of the latch 54.

The assembly head 26 is rotatably attached to the housing 40 by way of an axle 68 which passes through bearings 70, 72, a bore 76 in the housing 40 and a hub 78 and coupling 80. The axle 68 is retained in position by a clip 82 in a conventional manner along with a set screw 86.

As will be hereinafter discussed in great detail, the pump arm 36 with arcuate surface 34 is positioned with respect to the assembly head rollers 28 to provide a means for gradually compressing and sealing the collapsible and resilient tube 32 and thereafter gradually uncompressing the tube 32 in order to move a fluid (not shown) through the tube 32 in a direction indicated by the rotation area 92 without creating substantial fluid back pressure in a direction opposite that of the arrow 92. The spatial relationship provided by the mounting of the assembly head 26 and arcuate surface 32 is more clearly shown in Figure 3.

It should be appreciated that while four rollers 28 are shown mounted in a circular pattern about an assembly head axis 96, a larger or smaller number of rollers may be suitable depending upon pumping requirements. As shown each roller 28 includes a roller axis 100 which is generally parallel to the assembly head axis 96.

As shown in Figure 3, the arcuate surface 34 is configured and the pump arm 36 positioned with respect to the assembly head 26 so that as the assembly head 26 is rotated in the direction of arrow 92, each roller 28 successively contacts the tube 32, gradually compresses and seals the tube 32 during approximately a 45° rotation of the assembly head 26.

Further configuration of the arcuate surface 34 and position of the pump arm 36 with respect to the assembly head 26 enables each roller to gradually release the tube during a rotation of the assembly head 26 of about 45°. This configuration also enables each roller to remain in a sealing engagement with the tube 32 during approximately a 90° rotation of the assembly head 26.

This is to be contrasted with a prior art peristaltic pump 102 in which positioning of prior art assembly heads 104 with pump arm arcuate surfaces 106 is shown in Figure 4. In the prior art arrangement, sealing of the tube 108 occurs in a small angular rotation (in the direction of arrow 110) of the prior art assembly head 104. This results in movement of fluid within the prior art tube 108 away from the compressing prior art roller 112 which causes significant back pressure in the prior art tube 108 as indicated by the arrow 114.

To further enhance the efficient and reliable sealing of the tube 32 by the rollers 28 in the pump 10, according to the present invention, a specific circumferential surface 116 on the rollers 28 is provided, as shown in Figure 5.

As shown, each roller 28 has an inside diameter 118 which is smaller than roller diameters 120 at each end 122, 124 of each roller. This inside diameter 118 is constant between the end diameters 120 and the end diameters 120 are interconnected with the inside diameter 118 by arcuate surface 126.

This generally U-shaped cross-section of the roller provides for uniform sealing tube 32 as shown in Figure

5 which is not possible with a flat or uniform diameter roller 130, see Figure 5a. As shown in cross-section in Figure 5-A, the prior art roller 130 provides incomplete sealing of a tube 132 because the circular nature of the tube inside diameter results in end voids 134 136 unless sufficient pressure is exerted to collapsible the tube side 138.

However, such increased pressure by the rollers 112 may lead to excessive tube wear and may further result in a excess loading on the assembly head 104 and rollers 112.

In order to prevent movement of the tube 32 through the housing 40, collars 144 146 may be attached or molded into the tube at a spaced apart distance from one another in order that each collar is positioned abutting the housing front 40 upon assembly of the tube 32 into the housing 40 and around the rollers 28. The collar diameter is chosen in order to prevent entry of the collar into the housing means 40. It has been found that reliable and efficient performance of the pump is provided when the compressible and resilient tube is formed from silicon having a hardness of about 55 durometers, Shore A, platinum or peroxide cure method, and a typical tubing size is three-eighth inch. Preferably the tube is formed from a peroxide cure silicon, said cure being well known in the art.

This size tube enables pumping volumes of up to about 40 cc/minute when the assembly head is rotated at up to about 75 rpm.

The hereinabove described arrangement of the assembly head 26, rollers 28, and pump head 36 with arcuate surface 34 using the hereinabove referenced tube 32 configuration enables a significant reduction in back pressure as compared to a prior art peristaltic pump 102 having the same overall dimensions and operated at the same volume output. This is clearly shown in Figures 6 and 7 which are plots of the vacuum drawn by the pump as a function of time for pumping volumes of about 10 cc per minute and 40 cc per minute.

Curves A in both Figures 6 and 7 represent the prior art pump performance while Curves B in Figures 6 and 7 represent the results of a peristaltic pump configured in accordance with the present invention.

It can be easily seen from Figure 6 that the vacuum variation on the intake of the pump 10 in accordance with the present invention operating at about 10 ccs per minute is less than plus or minus 4 mm Hg at a vacuum of about 18 mm Hg. This is to be compared with the vacuum variation on the intake of the prior art pump 102 which is about plus or minus 8 mm Hg at 10 ccs per minute. Thus the change in back pressure of the pump 10 in accordance with the present invention over the prior art pump 102 is a factor of two.

An even greater inprovement in reduced vacuum variation or back pressure is exhibited by the pump 10 in accordance with the present invention when operating at a higher flow rate. This is shown in Figure 7 wherein the variation of vacuum for the pump 10 is about plus or minus 5 mm Hg whereas the variation of vacuum for the prior art pump 102 is about plus or minus 15 mm Hg. A factor of about 3 improvement.

Although there has been hereinabove described a specific peristaltic pump in accordance with the present invention, for the purpose of illustrating the manner in which the invention may be used to advantage, it should be appreciated that the invention is not limited thereto. Accordingly, any and all modifications, variations, or equivalent arrangements which may occur to those skilled in the art, should be considered to be within the scope of the present invention as defined in the appended claims.

Claims

1. A peristaltic pump (10) comprising:

   assembly head means (26) for supporting a plurality of rollers (28), said rollers (28) being mounted in an arcuate pattern about an assembly head axis (96), each roller (28) having a rotation axis generally parallel to the assembly head axis (96);
   a collapsible and resilient tube (32);
   housing means (40) for rotatably mounting said assembly head (26) and for guiding the collapsible and resilient tube (32) over said rollers (28);
   a pump arm (36) having an arcuate surface (34), the radius of which arcuate surface (34) is greater than the corresponding radius of the arc of travel of the rollers (28), the pump arm (36) being mounted to said housing means (40) in a position enabling said rollers (28) to compress the tube (32) against the arcuate surface (34) as the assembly head (26) is rotated, said arcuate surface (34) being shaped and positioned with respect to said assembly head (26) so that as the assembly head (26) is rotated, each roller (28) successively contacts the tube (32) and gradually seals the tube (32) during approximately a 45° rotation of the assembly head (26), said pump arm (36) being pivotally mounted to said housing means (40); and
   means (54) for rigidly positioning and locking the pump arms (36) in a closed position enabling said rollers (28) to compress the tube (32) against the arcuate surface (34), characterised in that said collapsible and resilient tube (32) comprises means for preventing movement of the tube through the housing means, and wherein each roller (28) has an inside diameter (118) that is smaller than roller diameters at each end (122, 124) of each roller (28).

2. The peristaltic pump according to Claim 1 wherein there are four rollers (28).

3. The peristaltic pump according to Claim 1 or Claim 2 wherein each roller (28) comprises means defining a circumferental surface thereon, for uniformly sealing the tube as each roller compresses the tubing.

4. The peristaltic pump according to any one of Claims 1 to 3 wherein said means for preventing movement of the tube (32) comprises at least one collar (144) disposed on said tube and having a dimension sufficient to prevent entry of the collar into the housing means (40).

5. The peristaltic pump according to any one of Claims 1 to 4 wherein each roller (28) has a constant diameter extending between end diameters (122, 124) of each roller (28), said end diameters (122, 124) being greater than said constant diameter.

6. The peristaltic pump according to Claim 5 wherein said end diameters (122, 124) are interconnected with said constant diameter by an arcuate surface (126).

Patentansprüche

1. Peristaltische Pumpe (10) mit:

einer Montagekopfeinrichtung (26) zur Halterung einer Vielzahl von Walzen (28), wobei die Walzen (28) in einem bogenförmigen Muster um eine Montagekopfachse (96) herum befestigt sind und jede Walze (28) eine Drehachse allgemein parallel zur Achse (96) des Montagekopfes aufweist,
einem zusammendrückbaren und elastischen Rohr (32),
einem Gehäuseteil (40) zur drehbaren Befestigung des Montagekopfes (26) und zur Führung des zusammendrückbaren und elastischen Rohres (32) über die Walzen (28),
einem Pumpenarm (36) mit einer bogenförmigen Oberfläche (34), wobei der Radius der bogenförmigen Oberfläche größer als der entsprechende Radius des Bewegungsbogens der Walzen (28) ist und der Pumpenarm (36) an dem Gehäuseteil (40) an einer Position befestigt ist, die es den Walzen (28) ermöglicht, das Rohr (32) gegen die bogenförmige Oberfläche (34) zusammenzudrücken, wenn der Montagekopf (26) in Drehung versetzt wird, wobei die bogenförmige Oberfläche (34) bezüglich des Montagekopfes (26) so geformt und angeordnet ist, daß bei der Drehung des Montagekopfes (26) jede Walze (28) aufeinanderfolgend mit dem Rohr (32) in Berührung kommt und das Rohr (32) graduell während einer Drehung von angenähert 45° des Montagekopfes (26) abdichtet, wobei der Pumpenarm (36) schwenkbar an dem Gehäuseteil (40) befestigt ist, und
einer Einrichtung (54) zur starren Positionierung und Verriegelung der Pumpenarme (36) in einem geschlossenen Zustand, in dem es den Walzen (28) ermöglicht wird, das Rohr (32) gegen die bogenförmige Oberfläche (34) zusammenzudrücken,

dadurch gekennzeichnet, daß das zusammendrückbare und elastische Rohr (32) Einrichtungen zur Verhinderung einer Bewegung des Rohres durch das Gehäuseteil umfaßt und daß jede Walze (28) einen innenliegenden Durchmesser (118) aufweist, der kleiner als die Walzendurchmesser an jedem Ende (122,124) jeder Walze (28) ist.

2. Peristaltische Pumpe nach Anspruch 1, bei der vier Walzen (28) vorgesehen sind.

3. Peristaltische Pumpe nach Anspruch 1 oder 2, bei der jede Walze (28) Einrichtungen zur Ausbildung einer Umfangsoberfläche auf dieser Walze zur gleichförmigen Abdichtung des Rohres umfaßt, während jede Walze das Rohr zusammendrückt.

4. Peristaltische Pumpe nach einem der Ansprüche 1 - 3, bei der die Einrichtung zur Verhinderung einer Bewegung des Rohres (22) zumindest einen Ringwulst (144) umfaßt, der auf dem Rohr angeordnet ist und eine Abmessung aufweist, die ausreicht, um den Eintritt des Ringwulstes in den Gehäuseteil (40) zu verhindern.

5. Peristaltische Pumpe nach einem der Ansprüche 1 - 4, bei der jede Walze (28) einen konstanten Durchmesser aufweist, der sich zwischen Enddurchmessern (122,124) jeder Walze (28) erstreckt, wobei die Enddurchmesser (122,124) größer als der konstante Durchmesser sind.

6. Peristaltische Pumpe nach Anspruch 5, bei der die Enddurchmesser (122,124) mit dem konstanten Durchmesser über eine bogenförmige Oberfläche (126) verbunden sind.

Revendications

1. Pompe péristaltique (10) comprenant :

des moyens formant tête d'assemblage (26) destinés à supporter une pluralité de rouleaux (28), lesdits rouleaux (28) étant montés selon une configuration courbe autour d'un axe de tête d'assemblage (96), chaque rouleau (28)

ayant un axe de rotation généralement parallèle à l'axe de tête d'assemblage (96) ;
un tube comprimable et élastique (32) ;
des moyens formant logement (40) pour monter, de manière rotative, ladite tête d'assemblage (26) et pour guider le tube comprimable et élastique (32) autour desdits rouleaux (28) ;
un bras de pompe (36) présentant une surface en forme d'arc (34), laquelle surface en forme d'arc (34) a un rayon plus grand que le rayon correspondant de l'arc de déplacement des rouleaux (28), le bras de pompe (36) étant monté sur lesdits moyens formant logement (40) dans une position permettant auxdits rouleaux (28) de comprimer le tube (32) contre la surface en forme d'arc (34) alors que la tête d'assemblage (26) est mise en rotation, ladite surface en forme d'arc (34) ayant une forme et étant positionnée par rapport à ladite tête d'assemblage (26) de sorte que, alors que la tête d'assemblage (26) est mise en rotation, chaque rouleau (28) entre successivement en contact avec le tube (32) et ferme progressivement le tube (32) au cours d'une rotation d'environ 45° de la tête d'assemblage (26), ledit bras de pompe (36) étant monté, de manière pivotante, sur lesdits moyens formant logement (40) ; et
des moyens (54) destinés à positionner et verrouiller, de manière rigide, les bras de pompe (36) dans une position fermée permettant auxdits rouleaux (28) de comprimer le tube (32) contre la surface en forme d'arc (34), caractérisée en ce que ledit tube comprimable et élastique (32) comprend des moyens destinés à empêcher le mouvement du tube à travers les moyens formant logement et dans laquelle chaque rouleau (28) a un diamètre intérieur (118) plus petit que les diamètres des rouleaux à chaque extrémité (122, 124) de chaque rouleau (28).

2. Pompe péristaltique selon la revendication 1, dans laquelle il y a quatre rouleaux (28).

3. Pompe péristaltique selon la revendication 1 ou la revendication 2, dans laquelle chaque rouleau (28) comprend des moyens définissant une surface circonférentielle sur celle-ci, pour fermer le tube, de manière uniforme alors que chaque rouleau comprime le tube.

4. Pompe péristaltique selon l'une quelconque des revendications 1 à 3, dans laquelle lesdits moyens destinés à empêcher le mouvement du tube (32) comprennent au moins un collier (144) disposé sur ledit tube et d'une dimension suffisante pour empêcher l'entrée du collier dans les moyens formant logement (40).

5. Pompe péristaltique selon l'une quelconque des revendications 1 à 4, dans laquelle chaque rouleau (28) a un diamètre constant s'étendant entre les diamètres d'extrémité (122, 124) de chaque rouleau (28), lesdits diamètres d'extrémité (122, 124) étant plus grands que ledit diamètre constant.

6. Pompe péristaltique selon la revendication 5, dans laquelle lesdits diamètres d'extrémité (122, 124) sont interconnectés avec ledit diamètre constant par un surface en forme d'arc (126).

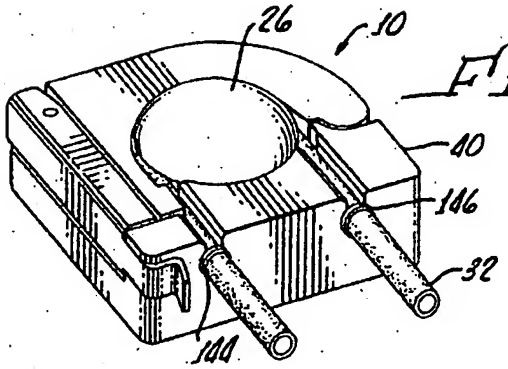
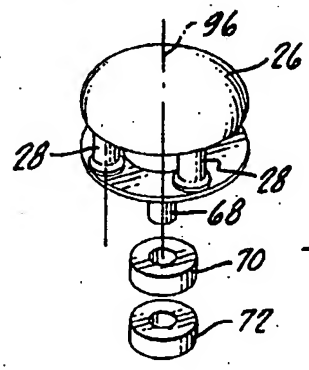

26
10
40
146
32
100

FIG. 1.


96
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70
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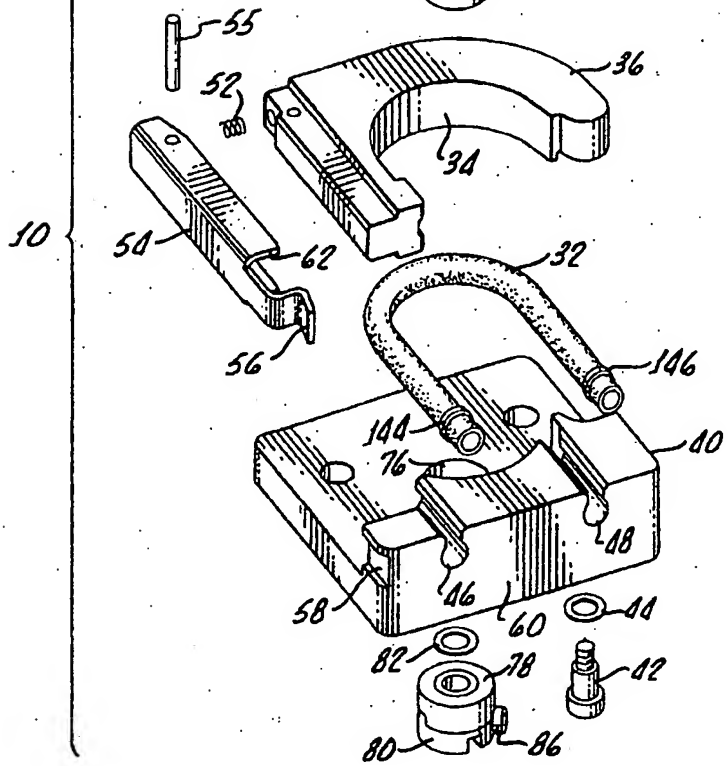
FIG. 2.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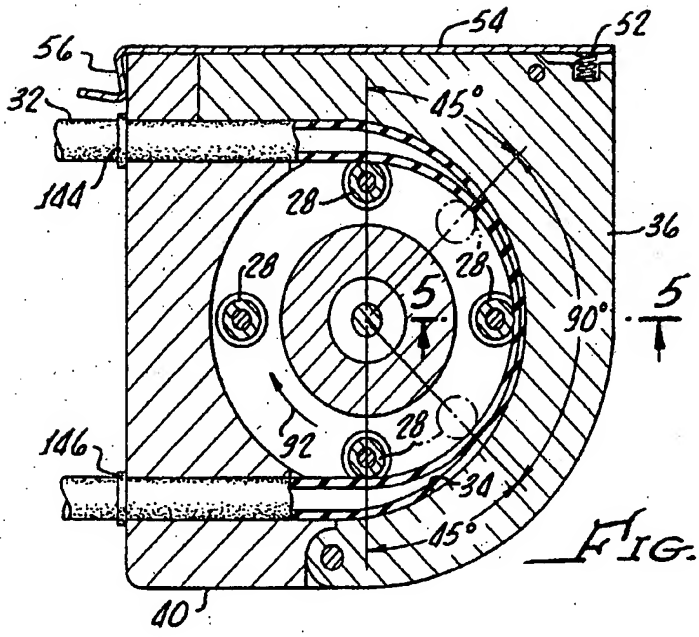


FIG. 3.

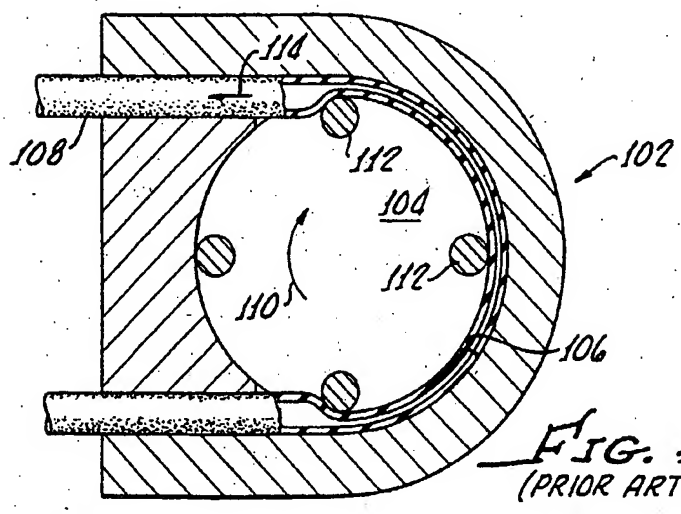


FIG. 4.
(PRIOR ART)

FIG. 5a. (PRIOR ART)

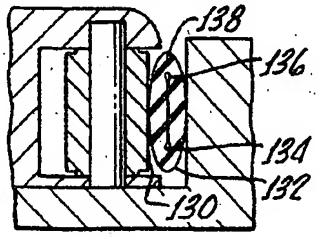


FIG. 5.

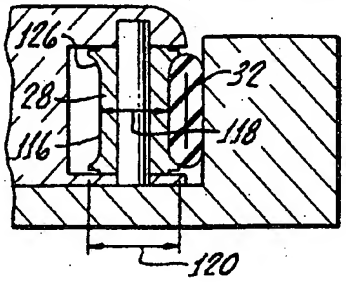


FIG. 6.

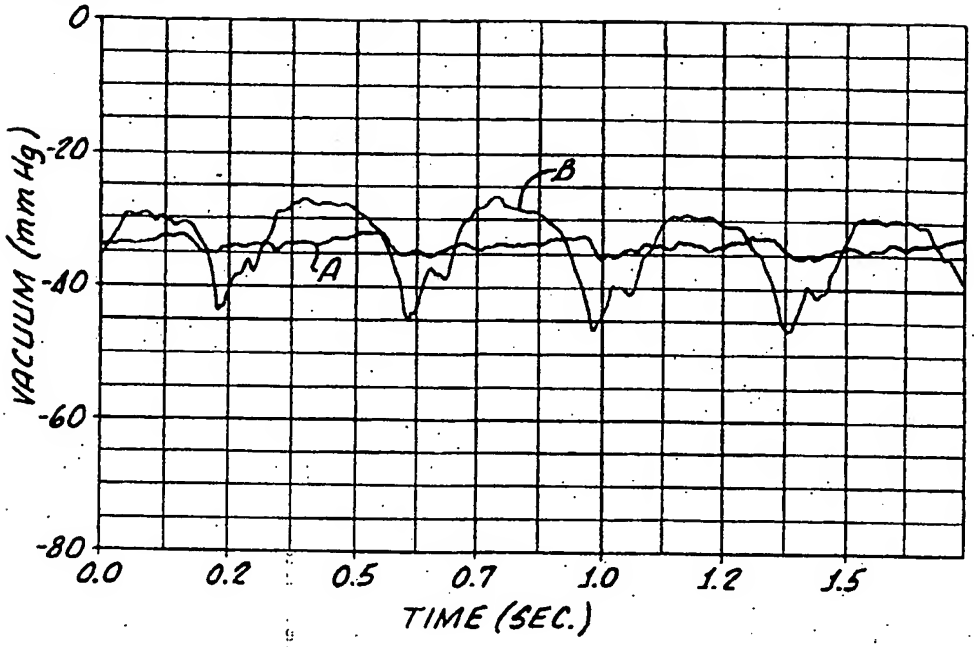
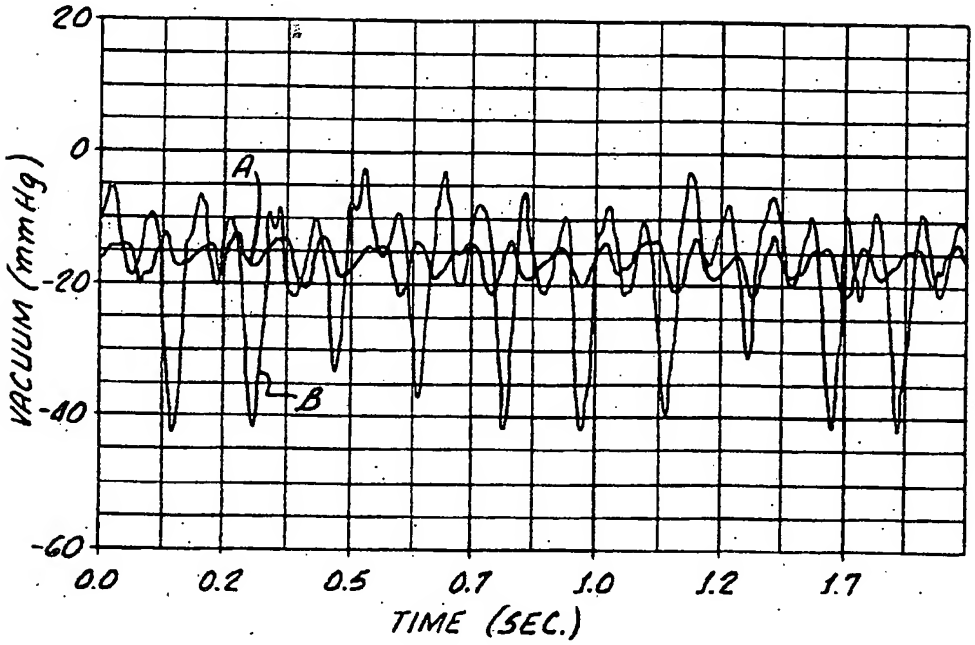

0
-20
-40
-60
-80
VACUUM (mm Hg)
A
B
0.0
0.2
0.5
0.7
1.0
1.2
1.5
TIME (SEC.)

FIG. 7.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1.7
TIME (SEC.)